NATIONAL HURRICANE CENTER FORECAST VERIFICATION REPORT

2020 HURRICANE SEASON

John P. Cangialosi
National Hurricane Center

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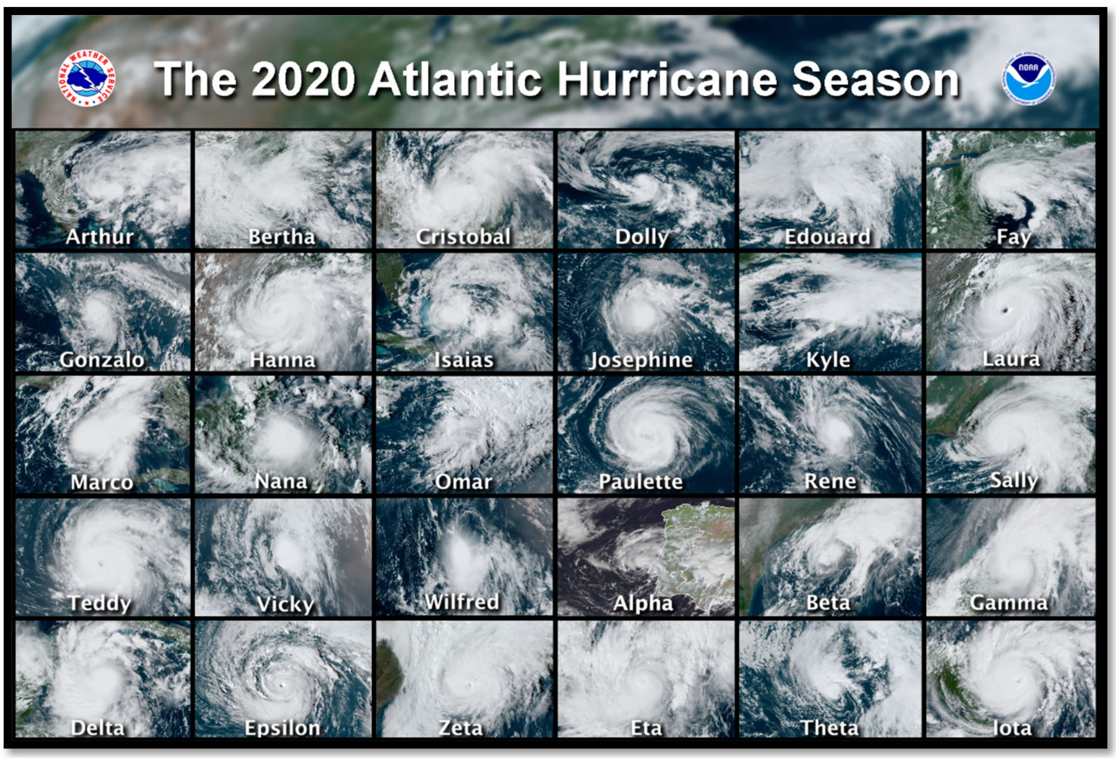

SATELLITE IMAGES OF THE UNPRECEDENTED 30 TROPICAL STORMS AND HURRICANES DURING THE 2020 ATLANTIC HURRICANE SEASON.

ABSTRACT

There were 597 official tropical cyclone forecasts issued during the 2020 Atlantic hurricane season, which is well above the long-term average number of forecasts and the second most during the last 30 years. The mean NHC official track forecast errors in the Atlantic basin were close to their 5-yr means. No records for track accuracy were set in 2020. Track forecast skill and error have generally changed little during the past few years, but there has been a notable increase in

track skill and decrease in error over the long term. The official track forecasts were slightly outperformed by the consensus models at some time periods. There was no clear winner among the individual models with GFSI, AEMI, CTCI, HMNI, and EMXI all being competeive with one another. HWFI, CMCI, EGRI, and NVGI performed less well. The Government Performance and Results Act of 1993 (GPRA) track goal was missed.

Mean official intensity errors for the Atlantic basin in 2020 were a little higher than the 5-yr means for the short lead times, but the errors were well below the means from 72 to 120 h. Decay-SHIFOR errors in 2020 followed a similar pattern to the official forecasts. The official forecasts were quite skillful and beat all of the models at 12 h, 72 h, and 96 h. No records for intensity accuracy were set in 2020. Among the guidance, IVCN and HCCA were the best performers. HWFI and CTCI were also quite skillful and were the best individual models. LGEM, DSHP, and HMNI were fair performers, and GFSI was competitive with those models for some of the forecast times. EMXI was less skillful. The GPRA intensity goal was just missed.

There were 256 official tropical cyclone forecasts issued in the eastern North Pacific basin in 2020, although only 29 of these verified at 120 h. This level of activity was well below average and the lowest number of forecasts since 2010. The mean NHC official track forecast errors in the east Pacific basin were a little higher than the previous 5-yr means at all forecast times. No records for track accuracy were set in 2020. The official track forecasts were very skillful, but they were outperformed by HCCA and TVCE at some time periods. There was no clear best individual model in this basin either, as EMXI, GFSI, HMNI, and EGRI all had similar skill levels. HWFI and CMCI were fair performers, but they were not competitive with the best models. NVGI lagged behind.

For intensity, the official forecast errors in the eastern North Pacific basin were notably lower than the 5-yr means for the short lead times, but slightly higher than the means for the longer lead times. Decay-SHIFOR errors were lower than their 5-yr means at all times, especially the longer lead times. Records for intensity accuracy were set from 12 to 48 h in 2020. The official forecasts were close to the consensus models and were skillful through 96 h, but the official forecasts and all of the models did not have any skill at 120 h. HWFI was the best individual model, and it had the highest skill of all of the guidance at 96 h.

An evaluation of track performance during the 2018-20 period in the Atlantic basin indicates that HCCA and TVCA were the best models, and EMXI was close behind. The official track forecasts for the 3-yr sample had skill that was quite close to the best aids throughout the forecast period. For intensity in the Atlantic basin, the official forecasts performed quite well and had skill that was comparable to the best guidance, the consensus models. HWFI and LGEM were the best individual models.

A three-year evaluation from 2018-20 in the eastern North Pacific indicates that the official track forecasts were very skillful, and they had skill levels close to the consensus models. Regarding intensity, the official forecasts during the 3-yr sample performed as good as or better than the consensus models in that basin.

Quantitative probabilistic forecasts of tropical cyclogenesis are expressed in 48 and 120 h time frames in 10% increments and in terms of categories (“low”, “medium”, or “high”). In the Atlantic basin, results from 2020 indicate that a low bias (under-forecast) existed at most probabilities for both the 48- and 120-h forecasts. In the eastern North Pacific basin, the 48-h and 120-h probabilistic forecasts were generally well calibrated.

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1. Introduction

For all operationally designated tropical or subtropical cyclones, or systems that could become tropical or subtropical cyclones and affect land within the next 48 h in the Atlantic and eastern North Pacific basins, the National Hurricane Center (NHC) issues an official forecast of the cyclone's center location and maximum 1-min surface wind speed. Forecasts are issued every 6 h, and contain projections valid 12, 24, 36, 48, 60, 72, 96, and 120 h after the forecast's nominal initial time (0000, 0600, 1200, or 1800 UTC)[1]. At the conclusion of the season, forecasts are evaluated by comparing the projected positions and intensities to the corresponding post-storm derived "best track" positions and intensities for each cyclone. A forecast is included in the verification only if the system is classified in the final best track as a tropical (or subtropical[2]) cyclone at both the forecast's initial time and at the projection's valid time. All other stages of development (e.g., tropical wave, [remnant] low, extratropical) are excluded[3]. For verification purposes, forecasts associated with special advisories do not supersede the original forecast issued for that synoptic time; rather, the original forecast is retained[4]. All verifications in this report include the depression stage.

It is important to distinguish between *forecast error* and *forecast skill*. Track forecast error, for example, is defined as the great-circle distance between a cyclone's forecast position and the best track position at the forecast verification time. Skill, on the other hand, represents a normalization of this forecast error against some standard or baseline. Expressed as a percentage improvement over the baseline, the skill of a forecast s_f is given by

$$s_f\,(\%) = 100 * (e_b - e_f) / e_b$$

where e_b is the error of the baseline model and e_f is the error of the forecast being evaluated. It is seen that skill is positive when the forecast error is smaller than the error from the baseline.

To assess the degree of skill in a set of track forecasts, the track forecast error can be compared with the error from CLIPER5, a climatology and persistence model that contains no information about the current state of the atmosphere (Neumann 1972, Aberson 1998)[5]. Errors from the CLIPER5 model are taken to represent a "no-skill" level of accuracy that is used as the baseline (e_b) for evaluating other forecasts[6]. If CLIPER5 errors are unusually low during a given season, for example, it indicates that the year's storms were inherently "easier" to forecast than normal or otherwise unusually well behaved. The current version of CLIPER5 is based on developmental data from 1931-2004 for the Atlantic and from 1949-2004 for the eastern Pacific.

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1 The nominal initial time represents the beginning of the forecast process. The actual advisory package is not released until 3 h after the nominal initial time, i.e., at 0300, 0900, 1500, and 2100 UTC.

2 For the remainder of this report, the term "tropical cyclone" shall be understood to also include subtropical cyclones.

3 Possible classifications in the best track are: Tropical Depression, Tropical Storm, Hurricane, Subtropical Depression, Subtropical Storm, Extratropical, Disturbance, Wave, and Low.

4 Special advisories are issued whenever an unexpected significant change has occurred or when watches or warnings are to be issued between regularly scheduled advisories. The treatment of special advisories in forecast databases changed in 2005 to the current practice of retaining and verifying the original advisory forecast.

5 CLIPER5 and SHIFOR5 are 5-day versions of the original 3-day CLIPER and SHIFOR models.

6 To be sure, some "skill", or expertise, is required to properly initialize the CLIPER model.

Particularly useful skill standards are those that do not require operational products or inputs, and can therefore be easily applied retrospectively to historical data. CLIPER5 satisfies this condition, since it can be run using persistence predictors (e.g., the storm's current motion) that are based on either operational or best track inputs. The best-track version of CLIPER5, which yields substantially lower errors than its operational counterpart, is generally used to analyze lengthy historical records for which operational inputs are unavailable. It is more instructive (and fairer) to evaluate operational forecasts against operational skill benchmarks, and therefore the operational versions are used for the verifications discussed below.[7]

Forecast intensity error is defined as the absolute value of the difference between the forecast and best track intensity at the forecast verifying time. Skill in a set of intensity forecasts is assessed using Decay-SHIFOR5 (DSHIFOR5) as the baseline. The DSHIFOR5 forecast is obtained by initially running SHIFOR5, the climatology and persistence model for intensity that is analogous to the CLIPER5 model for track (Jarvinen and Neumann 1979, Knaff et al. 2003). The output from SHIFOR5 is then adjusted for land interaction by applying the decay rate of DeMaria et al. (2006). The application of the decay component requires a forecast track, which here is given by CLIPER5. The use of DSHIFOR5 as the intensity skill benchmark was introduced in 2006. On average, DSHIFOR5 errors are about 5-15% lower than SHIFOR5 in the Atlantic basin from 12-72 h, and about the same as SHIFOR5 at 96 and 120 h.

It has been argued that CLIPER5 and DSHIFOR5 should not be used for skill benchmarks, primarily on the grounds that they were not good measures of forecast difficulty. Particularly in the context of evaluating forecaster performance, it was recommended that a model consensus (see discussion below) be used as the baseline. However, an unpublished study by NHC has shown that on the seasonal time scales at least, CLIPER5 and DSHIFOR5 are indeed good predictors of official forecast error. For the period 1990-2009 CLIPER5 errors explained 67% of the variance in annual-average NHC official track forecast errors at 24 h. At 72 h the explained variance was 40% and at 120 h the explained variance was 23%. For intensity the relationship was even stronger: DSHIFOR5 explained between 50 and 69% of the variance in annual-average NHC official errors at all time periods. Given this, CLIPER5 and DSHIFOR5 appear to remain suitable, if imperfect, baselines for skill, in the context of examining forecast performance over the course of a season (or longer). However, they're probably less useful for interpreting forecast performance with smaller samples (e.g., for a single storm).

The trajectory-CLIPER (TCLP) model is an alternative to the CLIPER and SHIFOR models for providing baseline track and intensity forecasts (DeMaria, personal communication). The input to TCLP [Julian Day, initial latitude, longitude, maximum wind, and the time tendencies of position and intensity] is the same as for CLIPER/SHIFOR, but rather than using linear regression to predict the future latitude, longitude and maximum wind, a trajectory approach is used. For track, a monthly climatology of observed storm motion vectors was developed from a 1982-2011 sample. The TCLP storm track is determined from a trajectory of the climatological motion vectors starting at the initial date and position of the storm. The climatological motion vector is modified

[7] On very rare occasions, operational CLIPER or SHIFOR runs are missing from forecast databases. To ensure a completely homogeneous verification, post-season retrospective runs of the skill benchmarks are made using operational inputs. Furthermore, if a forecaster makes multiple estimates of the storm's initial motion, location, etc., over the course of a forecast cycle, then these retrospective skill benchmarks may differ slightly from the operational CLIPER/SHIFOR runs that appear in the forecast database.

by the current storm motion vector, where the influence of the current motion vector decreases with time during the forecast. A similar approach is taken for intensity, except that the intensity tendency is estimated from the logistic growth equation model (LGEM) with climatological input. Similar to track, the climatological intensity tendency is modified by the observed tendency, where the influence decreases with forecast time. The track used for the TCLP intensity forecast is the TCLP track forecast. When the storm track crosses land, the intensity is decreased at a climatological decay rate. A comparison of a 10-yr sample of TCLP errors with those from CLIPER5 and DSHIFOR5 shows that the average track and intensity errors of the two baselines are within 10% of each other at all forecast times out to five days for the Atlantic and eastern North Pacific. One advantage of TCLP over CLIPER5/DSHIFOR5 is that TCLP can be run to any desired forecast time.

NHC also issues forecasts of the size of tropical cyclones; these “wind radii” forecasts are estimates of the maximum extent of winds of various thresholds (34, 50, and 64 kt) expected in each of four quadrants surrounding the cyclone. Unfortunately, there is insufficient surface wind information to allow the forecaster to accurately analyze the size of a tropical cyclone’s wind field. As a result, post-storm best track wind radii are likely to have errors so large as to render a verification of official radii forecasts unreliable and potentially misleading; consequently, no verifications of NHC wind radii are included in this report. In time, as our ability to measure the surface wind field in tropical cyclones improves, it may be possible to perform a meaningful verification of NHC wind radii forecasts (Cangialosi and Landsea 2016).

Numerous objective forecast aids (guidance models) are available to help the NHC in the preparation of official track and intensity forecasts. Guidance models are characterized as either *early* or *late*, depending on whether or not they are available to the forecaster during the forecast cycle. For example, consider the 1200 UTC (12Z) forecast cycle, which begins with the 12Z synoptic time and ends with the release of an official forecast at 15Z. The 12Z run of the National Weather Service/Global Forecast System (GFS) model is not complete and available to the forecaster until about 16Z, or about an hour after the NHC forecast is released. Consequently, the 12Z GFS would be considered a late model since it could not be used to prepare the 12Z official forecast. This report focuses on the verification of early models.

Multi-layer dynamical models are generally, if not always, late models. Fortunately, a technique exists to take the most recent available run of a late model and adjust its forecast to apply to the current synoptic time and initial conditions. In the example above, forecast data for hours 6-126 from the previous (06Z) run of the GFS would be smoothed and then adjusted, or shifted, such that the 6-h forecast (valid at 12Z) would match the observed 12Z position and intensity of the tropical cyclone. The adjustment process creates an “early” version of the GFS model for the 12Z forecast cycle that is based on the most current available guidance. The adjusted versions of the late models are known, mostly for historical reasons, as *interpolated* models[8]. The adjustment algorithm is invoked as long as the most recent available late model is not more than 12 h old, e.g., a 00Z late model could be used to form an interpolated model for

[8] When the technique to create an early model from a late model was first developed, forecast output from the late models was available only at 12 h (or longer) intervals. In order to shift the late model’s forecasts forward by 6 hours, it was necessary to first interpolate between the 12 h forecast values of the late model – hence the designation “interpolated”.

the subsequent 06Z or 12Z forecast cycles, but not for the subsequent 18Z cycle. Verification procedures here make no distinction between 6 and 12 h interpolated models.[9]

A list of models is given in Table 1. In addition to their timeliness, models are characterized by their complexity or structure; this information is contained in the table for reference. Briefly, *dynamical* models forecast by solving the physical equations governing motions in the atmosphere. Dynamical models may treat the atmosphere either as a single layer (two-dimensional) or as having multiple layers (three-dimensional), and their domains may cover the entire globe or be limited to specific regions. The interpolated versions of dynamical model track and intensity forecasts are also sometimes referred to as dynamical models. *Statistical* models, in contrast, do not consider the characteristics of the current atmosphere explicitly but instead are based on historical relationships between storm behavior and various other parameters. *Statistical-dynamical* models are statistical in structure but use forecast parameters from dynamical models as predictors. *Consensus* models are not true forecast models *per se*, but are merely combinations of results from other models. One way to form a consensus is to simply average the results from a collection (or "ensemble") of models, but other, more complex techniques can also be used. The HCCA model, for example, combines its individual components on the basis of past performance and attempts to correct for biases in those components (Simon et al. 2018). A consensus model that considers past error characteristics can be described as a "weighted" or "corrected" consensus. Additional information about the guidance models used at the NHC can be found at http://www.nhc.noaa.gov/modelsummary.shtml.

The verifications described in this report are for all tropical cyclones in the Atlantic and eastern North Pacific basins. These statistics are based on forecast and best track data sets taken from the Automated Tropical Cyclone Forecast (ATCF) System[10] on 27 May 2021 for the Atlantic basin, and on 26 April 2021 for the eastern North Pacific basin. Verifications for the Atlantic and eastern North Pacific basins are given in Sections 2 and 3 below, respectively. Section 4 discusses NHC's probabilistic genesis forecasts. Section 5 summarizes the key findings of the 2020 verification and previews anticipated changes for 2021.

2. Atlantic Basin

a. 2020 season overview – Track

Figure 1 and Table 2 present the results of the NHC official track forecast verification for the 2020 season, along with results averaged for the previous 5-yr period, 2015-2019. In 2020, the NHC issued 597 Atlantic basin tropical cyclone forecasts[11], a number nearly double the long term mean (322) and the second-most forecasts during the last 30 years, behind only 2005 (Fig. 2). Mean track errors ranged from 24 n mi at 12 h to 190 n mi at 120 h. The mean official track forecast errors in 2020 were similar to the previous 5-yr means from 12 to 96 h, but about 10%

[9] The UKM and EMX models are only available through 120 h twice a day (at 0000 and 1200 UTC). Consequently, roughly half the interpolated forecasts from these models are 12 h old.
[10] In ATCF lingo, these are known as the "a decks" and "b decks", respectively.
[11] This count does not include forecasts issued for systems later classified to have been something other than a tropical cyclone at the forecast time.

larger than the mean at 120 h. The CLIPER errors for 2020 were close to their 5-yr means for the shorter lead times, but notably smaller than their long-term means from 72 to 120 h. No records for track accuracy were set in 2020. The official track forecast vector biases were small through 96 h, but a notable southward bias (i.e., the official forecast tended to fall to the south of the verifying position) existed at 120 h. Track forecast skill ranged from 48% at 12 h to 69% at 48 and 60 h (Table 2). The track errors in 2020 decreased from the 2019 values at 24 and 48 h, but increased from 72 to 120 h.

Over the past 30 years, the 24−72-h track forecast errors have been reduced by 70 to 75% (Fig. 3a). Track forecast error reductions of about 60% have occurred over the past 15 to 20 years for the 96- and 120-h forecast periods. An evaluation of track skill indicates that there has been a gradual increase in skill over the long term (Fig. 3b). Although the long-term trends are quite well established, the track error and skill levels have levelled off during the past several years. Figure 4 indicates that on average the NHC track errors decrease as the initial intensity of a cyclone increases, and that relationship holds true through the 120-h forecast period.

Note that the mean official error in Figure 1 is not precisely zero at 0 h (the analysis time). This non-zero difference between the operational analysis of storm location and best track location, however, is not properly interpreted as “analysis error”. The best track is a subjectively smoothed representation of the storm history over its lifetime, in which the short-term variations in position or intensity that cannot be resolved in a 6-hourly time series are deliberately removed. Thus the location of a strong hurricane with a well-defined eye might be known with great accuracy at 1200 UTC, but the best track may indicate a location elsewhere by 5-10 miles or more if the precise location of the cyclone at 1200 UTC was unrepresentative. Operational analyses tend to follow the observed position of the storm more closely than the best track analyses, since it is more difficult to determine unrepresentative behavior in real time. Consequently, the t=0 “errors” shown in Figure 1 contain both true analysis error and representativeness error.

Table 3a presents a homogeneous[12] verification for the official forecast along with a selection of early models for 2020. In order to maximize the sample size, a guidance model had to be available at least two-thirds of the time at both 48 and 120 h to be included in this comparison. The performance of the official forecast and the early track models in terms of skill are presented in Figure 5. The figure shows that the official forecasts were highly skillful, and near the best models throughout the forecast period. The best models were the consensus aids FSSE, HCCA, and TVCA, which had slightly lower errors than the official forecasts at some time periods. Among the individual models, there was no clear best performer. GFSI was the best model from 36 to 72 h, but CTCI and HMNI had the highest skill values at 96 and 120 h. AEMI and EMXI were competitive with the best models as well. HWFI, CMCI, and EGRI performed less well, and NVGI lagged behind.

An evaluation over the three years 2018-20 (Fig. 6) indicates that HCCA and TVCA were the best models, and the official forecasts had about the same skill levels as those models throughout the forecast period. EMXI was the best individual model, but it had less skill than the

[12] Verifications comparing different forecast models are referred to as *homogeneous* if each model is verified over an identical set of forecast cycles. Only homogeneous model comparisons are presented in this report.

official forecasts and the consensus aids. EGRI, GFSI, AEMI, and HWFI were fair performers and had skill levels about 10-15% lower than the best performing models and official forecasts.

Vector biases of the guidance models for 2020 are given in Table 3b. The table shows that the official forecast had similar biases to the consensus aids, which all had a south or southeast bias at 120 h. GFSI and EGRI had large south and southeast biases at 120 h, respectively. Figure 7 shows a homogenous comparison of the 120-h biases of the official forecasts, GFSI, EXMI, and EGRI from 2018-20 in the Atlantic basin. It can be seen that mean biases (denoted by the red X) were generally south or southeast in the models and NHC forecasts. EGRI had the largest biases for this sample.

A separate homogeneous verification of the primary consensus models for 2020 is shown in Figure 8. The figure shows that HCCA was the most skillful model overall, but TVCA, TVDG, TVCX, FSSE, and GFEX had only slightly less skill. In constrast, AEMI was notably less skillful than the remainder of the guidance shown.

Atlantic basin 48-h official track error, evaluated for all tropical cyclones, is a forecast measure tracked under the Government Performance and Results Act of 1993 (GPRA). In 2020, the GPRA goal was 59 n mi and the verification for this measure was 64.5 n mi.

b. 2020 season overview – Intensity

Figure 9 and Table 4 present the results of the NHC official intensity forecast verification for the 2020 season, along with results averaged for the preceding 5-yr period. Mean forecast errors in 2020 ranged from 6 kt at 12 h to 13 kt at 120 h. These errors were a little above the 5-yr means from 12 h to 48 h, but about 15 to 20% lower than the 5-yr means from 72 to 120 h. No records for accuracy were set in 2020. The official forecasts had a slight high bias from 12 to 96 h, but a more notable low bias existed at 120 h. The Decay-SHIFOR5 errors had a similar pattern to the official forecast errors, with the errors being a little higher than their means in the short term, but more notably lower than their mean at the longer lead times. Figure 10 indicates that the NHC official errors at 24 and 48 h increased from 2019, but the 72 to 120 h errors decreased significantly. Over the long-term, despite year-to-year variability, there has been a notable decrease in error that began around 2010. It appears that the intensity predictions are gradually improving as the forecasts are generally more skillful in the past 10 years than they were in the 1990s and the first decade of the 2000s (Cangialosi et. al 2020).

Table 5a presents a homogeneous verification for the official forecasts and the primary early intensity models for 2020. Intensity biases are given in Table 5b, and forecast skill is presented in Figure 11. The official forecasts were quite skillful, and they beat all of the models at 12 h, 72 h, and 96 h. The consensus models IVCN and HCCA were the best aids, and they outperformed the official forecasts at some of the time periods. FSSE had similar skill to IVCN and HCCA for the short lead times, but it trailed off after 60 h. Among the individual models, HWFI was the best model at most time periods, but CTCI was also a strong performer. HMNI, DSHP, and LGEM were less skillful, but still fair performers. GFSI was competitive with the fair-performing models after 36 h while EMXI generally lagged behind. An inspection of the intensity biases (Table 5b) indicates that all of the models had small biases, except for GFSI and EMXI, which had large low biases at the longer lead times.

An evaluation over the three years 2018-20 (Fig. 12) indicates that the official forecasts have been consistently performing quite well, and had skill values close to the best aids IVCN and HCCA. For this sample, HWFI was the best individual model from 12 to 60 h, DSHP was best at 72 h, and LGEM had the most skill from 72 to 120 h. GFSI was competitive with the standard intensity models, but EMXI had slightly less skill.

The 48-h official intensity error, evaluated for all tropical cyclones, is another GPRA measure for the NHC. In 2020, the GPRA goal was 11 kt and the verification for this measure was 11.6 kt.

c. Verifications for individual storms

Forecast verifications for individual storms are given in Table 6. Of note are the large track errors for Hurricane Paulette at the longer forecast lead times. The poor track forecasts were associated with a slow bias during Paulette's recurvature near Bermuda and its quick northeast motion until extratropical transition occurred. Conversely, the official track forecast errors were quite low for some of the tropical cyclones near the U.S., including Laura and Cristobal. Figure 13 shows an illustration of the official track errors stratified by storm.

With regards to intensity, Hurricane Zeta was one of the more challenging cyclones to predict in 2020. The official intensity forecast errors were notably higher than the 5-yr averages at most forecast times, and Decay-SHIFOR errors were quite high as well, indicating the storm was challenging to forecast. In particular, Zeta's rapid intensification over the Gulf of Mexico was not forecast by NHC or any of the models even as the intensification was beginning. Figure 14 shows an illustration of the official intensity errors stratified by storm. Additional discussion on forecast performance for individual storms can be found in NHC Tropical Cyclone Reports available at http://www.nhc.noaa.gov/data/tcr/index.php?season=2020&basin=atl

3. Eastern North Pacific Basin

a. 2020 season overview – Track

The NHC track forecast verification for the 2020 season in the eastern North Pacific, along with results averaged for the previous 5-yr period is presented in Figure 15 and Table 7. There were 256 forecasts issued for the eastern Pacific basin in 2020, which was the lowest number of forecasts in this basin since 2010, and well below the long-term mean of 328 (Fig. 16). Since most of the tropical cyclones in the basin were short-lived, only 29 forecasts verified at 120 h. Mean track errors ranged from 24 n mi at 12 h to 148 n mi at 120 h. These errors were a little higher than the 5-yr means, and about 20% higher than the mean at 120 h. The CLIPER errors were also higher than their 5-yr means, indicating that the track of the season's storms were more challenging to predict than normal. No records for accuracy were set for track in this basin in 2020. The official track forecast vector biases were small through 96 h, but a more notable south to southeast bias existed at 96 and 120 h.

Figure 17 shows recent trends in track forecast accuracy and skill for the eastern North Pacific. Track errors have been dramatically reduced by about 70% for the 24- to 72-h forecasts since 1990, however, there has been little change in the errors during the past five years or so. At the 96- and 120-h forecast times, errors have dropped by about 60% since 2001, but like the short lead times, the error trends have been relatively flat during the past few years. Forecast skill in 2020 was higher than the 2019 values at all forecast times, but like track error there appears to be little trend in track skill values during the past several years.

Table 8a presents a homogeneous verification for the official forecast and the early track models for 2020, with vector biases of the guidance models given in Table 8b. Skill comparisons of selected models are shown in Fig. 18. The official forecasts were very skillful and near the best models, the consensus aids. HCCA was the best aid overall, and it beat the official forecasts from 12 to 72 h. TVCE was the next best model, also beating the official forecasts from 12 to 36 h. FSSE was competitive with TVCE and HCCA but it had lower skill than both of those consensus aids at all forecast times. It was quite mixed bag concerning which individual model outperformed another. HMNI and EGRI were the best aids at 12 and 24 h, EMXI was best from 36-60 h and at 120 h, and GFSI was best at 72 and 96 h. HWFI and CMCI were less skillful and NVGI was not competitive. The official forecasts had smaller track biases than most of the models at 96 and 120 h in 2020. Among the models, EGRI and EMXI had a significant southwest bias at 96 and 120 h, and GFSI had a large east-southeast bias at the same forecast time periods

An evaluation of the three years 2018-20 (Fig. 19) indicates that the official forecasts were very skillful, and they were near the performance of the consensus models. HCCA slightly bested the official forecasts in the short term, but it had about the same amount of skill as the official forecast for the longer lead times. Regarding the individual models, EMXI was the best performer from 12 to 72 h, but AEMI had about equal skill from 72 to 120 h. GFSI and HWFI were next best, but EGRI and CMCI performed less well. It should be noted that the dip in skill at 60 h is due to the small sample, which NHC only began in 2020.

A separate verification of the primary consensus aids is given in Figure 20. The skill of the consensus models was tightly clustered, but HCCA, TVCX, and TVDG were the best aids in the short term and GFEX was best at the longer range forecast times. AEMI was less skillful (about 10% lower skill) than the highest performers.

b. 2020 season overview – Intensity

Figure 21 and Table 9 present the results of the NHC eastern North Pacific intensity forecast verification for the 2020 season, along with results averaged for the preceding 5-yr period. Mean forecast errors were 5 kt at 12 h and increased to 18 kt at 96 h. The errors were up to 35% lower than the 5-yr means from 12 to 48 h, but slightly higher than the 5-yr means at 72 and 96 h. The Decay-SHIFOR forecast errors were lower than their 5-yr means at all times, especially at 120 h where the 2020 errors were 38% smaller than normal. Records for accuracy were set from 12 to 48 h in 2020. A review of error and skill trends (Fig. 22) indicates that although there is considerable year-to-year variability in intensity errors, there has been a decrease in error over the past couple of decades at most forecast times, which has accelerated some during the past few years. Forecast skill has changed little during the last several years, however. Intensity forecast biases were slightly high (over-forecast) from 12 to 72 h, and low (under-forecast) at 120 h.

Figure 23 and Table 10a present a homogeneous verification for the primary early intensity models for 2020. Forecast biases are given in Table 10b. The official forecasts were quite skillful and near the best models from 12 to 36 h, but the skill decreased significantly beyond that and there was little to no skill at 96 and 120 h. In fact, a similar trend is noted in all of the guidance with no model having skill at 120 h. This appears to be partly, if not mostly, associated with the low long lead-time Decay-SHIFOR errors. Among the individual models, HWFI was the best performer, and it even beat the official forecasts and the consensus models at 72 and 96 h. HMNI was a fairly good performer as well, especially for the short lead times. DSHP and LGEM were not as good as the purely dynamical models, and their skill fell sharply beyond 36 h. GFSI had a marginal amount of skill from 12 to 72 h and EMXI was generally not skillful. HWFI and HMNI had a slight low bias while DSHP, HCCA, and the official forecasts had a high bias, especially for the short lead times. An evaluation over the three years 2018-20 (Fig. 24) indicates a very different result than the 2020 sample alone. The official forecasts were skillful at all times and outperformed all of the guidance at 12 and 120 h, and they were competitive with the best aids HCCA and IVCN at the other forecast times. HWFI was the next best model, followed by HMNI and then DSHP and LGEM. GFSI had little skill while EMXI was generally not skillful.

c. Verifications for individual storms

Forecast verifications for individual storms are given for reference in Table 11. Additional discussion on forecast performance for individual storms can be found in NHC Tropical Cyclone Reports available at http://www.nhc.noaa.gov/data/tcr/index.php?season=2020&basin=epac.

4. Genesis Forecasts

The NHC routinely issues Tropical Weather Outlooks (TWOs) for both the Atlantic and eastern North Pacific basins. The TWOs are text products that discuss areas of disturbed weather and their potential for tropical cyclone development. Beginning in 2007, forecasters subjectively assigned a probability of genesis (0 to 100%, in 10% increments) to each area of disturbed weather described in the TWO, where the assigned probabilities represented the forecaster's determination of the chance of tropical cyclone formation during the 48-h period following the nominal TWO issuance time. NHC added probabilistic tropical cyclone forecasts through 120 h beginning in 2013. Verification is based on NHC best-track data, with the time of genesis defined to be the first tropical cyclone point appearing in the best track.

Verifications of the 48-h outlook for the Atlantic and eastern North Pacific basins for 2020 are given in Table 12 and illustrated in Figure 25. In the Atlantic basin, a total of 1081 genesis forecasts were made. These 48-h forecasts exhibited a slight low bias at most probabilities. In the eastern Pacific, a total of 884 genesis forecasts were made. The forecasts in this basin were generally well calibrated.

Verifications of the 120-h outlook for the Atlantic and eastern North Pacific basins for 2020 are given in Table 13 and illustrated in Figure 26. In the Atlantic basin, the 120-h forecasts, like the short-range forecasts, also had a low bias at most probabilities. In the eastern North Pacific, the genesis forecasts were generally reliable and well calibrated, except for a slight low bias between the 40 and 70% probabilities. The diagrams also show the refinement distribution, which indicates how often the forecasts deviated from (a perceived) climatology. Sharp peaks at climatology indicate low forecaster confidence, while maxima at the extremes indicate high confidence; the refinement distributions shown here suggest an intermediate level of forecaster confidence.

5. Looking Ahead to 2021

a. Track Forecast Cone Sizes

The National Hurricane Center track forecast cone depicts the probable track of the center of a tropical cyclone, and is formed by enclosing the area swept out by a set of circles along the forecast track (at 12, 24, 36 h, etc.). The size of each circle is set so that two-thirds of historical official forecast errors over the most-recent 5-yr sample fall within the circle. The circle radii defining the cones in 2021 for the Atlantic and eastern North Pacific basins (based on error distributions for 2016-20) are given in Table 14. In the Atlantic basin, the cone circles will be largely unchanged from last year. In the eastern Pacific basin, the cone circles will be slightly smaller from 24-96 h, and unchanged at the other forecast times. It should be noted that 60-h cone circles are now included, since NHC will continue making operational forecasts at that forecast time, and are based on interpolation of the 48- and 72-h cone sizes.

b. Consensus Models

In 2008, NHC changed the nomenclature for many of its consensus models. The new system defines a set of consensus model identifiers that remain fixed from year to year. The specific members of these consensus models, however, will be determined at the beginning of each season and may vary from year to year.

Some consensus models require all of their member models to be available in order to compute the consensus (e.g.,GFEX, ICON), while others are less restrictive, requiring only two or more members to be present (e.g., TVCA, IVCN). The terms “fixed” and “variable” can be used to describe these two approaches, respectively. In a variable consensus model, it is often the case that the 120-h forecast is based on a different set of members than the 12-h forecast. While this approach greatly increases availability, it does pose consistency issues for the forecaster.

The consensus model composition for 2021 is given in Table 15. The consensus models are unchanged from their compositions in 2020.

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List of Tables

Table 1. National Hurricane Center forecasts and models.

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
OFCL	Official NHC forecast			Trk, Int
HWRF	Hurricane Weather and Research Forecasting Model	Multi-layer regional dynamical	L	Trk, Int
HMON	Hurricanes in a Multi-scale Ocean-coupled Non-hydrostatic model	Multi-layer regional dynamical	L	Trk, Int
GFSO	NWS/Global Forecast System (formerly Aviation)	Multi-layer global dynamical	L	Trk, Int
AEMN	GFS ensemble mean	Consensus	L	Trk, Int
UKM	United Kingdom Met Office model, automated tracker	Multi-layer global dynamical	L	Trk, Int
EGRR	United Kingdom Met Office model with subjective quality control applied to the tracker	Multi-layer global dynamical	L	Trk, Int
UEMN	UKMET ensemble mean	Consensus	L	Trk, Int
NVGM	Navy Global Environmental Model	Multi-layer global dynamical	L	Trk, Int
CMC	Environment Canada global model	Multi-level global dynamical	L	Trk, Int
NAM	NWS/NAM	Multi-level regional dynamical	L	Trk, Int
CTX	COAMPS-TC using GFS initial and boundary conditions	Multi-layer regional dynamical	L	Trk, Int
EMX	ECMWF global model	Multi-layer global dynamical	L	Trk, Int
EEMN	ECMWF ensemble mean	Consensus	L	Trk

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
TABS	Beta and advection model (shallow layer)	Single-layer trajectory	E	Trk
TABM	Beta and advection model (medium layer)	Single-layer trajectory	E	Trk
TABD	Beta and advection model (deep layer)	Single-layer trajectory	E	Trk
CLP5	CLIPER5 (Climatology and Persistence model)	Statistical (baseline)	E	Trk
SHF5	SHIFOR5 (Climatology and Persistence model)	Statistical (baseline)	E	Int
DSF5	DSHIFOR5 (Climatology and Persistence model)	Statistical (baseline)	E	Int
OCD5	CLP5 (track) and DSF5 (intensity) models merged	Statistical (baseline)	E	Trk, Int
TCLP	Trajectory-CLIPER model	Statistical (baseline)	E	Trk, Int
SHIP	Statistical Hurricane Intensity Prediction Scheme (SHIPS)	Statistical-dynamical	E	Int
DSHP	SHIPS with inland decay	Statistical-dynamical	E	Int
OFCI	Previous cycle OFCL, adjusted	Interpolated	E	Trk, Int
HWFI	Previous cycle HWRF, adjusted	Interpolated-dynamical	E	Trk, Int
HMNI	Previous cycle HMON, adjusted	Interpolated-dynamical	E	Trk, Int
CTCI	Previous cycle CTCX, adjusted	Interpolated-dynamical	E	Trk, Int
GFSI	Previous cycle GFS, adjusted	Interpolated-dynamical	E	Trk, Int
UKMI	Previous cycle UKM, adjusted	Interpolated-dynamical	E	Trk, Int

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
EGRI	Previous cycle EGRR, adjusted	Interpolated-dynamical	E	Trk, Int
NVGI	Previous cycle NVGM, adjusted	Interpolated-dynamical	E	Trk, Int
EMXI	Previous cycle EMX, adjusted	Interpolated-dynamical	E	Trk, Int
CMCI	Previous cycle CMC, adjusted	Interpolated-dynamical	E	Trk, Int
AEMI	Previous cycle AEMN, adjusted	Consensus	E	Trk, Int
UEMI	Previous cycle UEMN, adjusted	Consensus	E	Trk, Int
FSSE	FSU Super-ensemble	Corrected consensus	E	Trk, Int
GFEX	Average of GFSI and EMXI	Consensus	E	Trk
TVCN	Average of at least two of GFSI EGRI HWFI EMXI CTCI	Consensus	E	Trk
TVCA	Average of at least two of GFSI EGRI HWFI EMXI CTCI	Consensus	E	Trk
TVCE	Average of at least two of GFSI EGRI HWFI EMXI CTCI	Consensus	E	Trk
TVCX	EMXI and average of at least two of GFSI EGRI HWFI EMXI CTCI	Consensus	E	Trk
TVCC	Version of TVCN corrected for model biases	Corrected consensus	E	Trk
TVDG	GFSI (double weight) EMXI (double weight) EGRI (double weight) CTCI HWFI	Corrected consensus	E	Trk
HCCA	Weighted average of AEMI, GFSI, CTCI, DSHP, EGRI, EMNI, EMXI,HWFI, HMNI LGEM	Corrected consensus	E	Trk, Int

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
ICON	Average of DSHP, LGEM, CTCI, HMNI and HWFI	Consensus	E	Int
IVDR	CTCI (double weight) HWFI (double weight) HMNI (double weight) GFSI DSHP LGEM	Consensus	E	Int
IVCN	Average of at least two of DSHP LGEM HWFI HMNI CTCI	Consensus	E	Int

Table 2. Homogenous comparison of official and CLIPER5 track forecast errors in the Atlantic basin in 2020 for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
2020 mean OFCL error (n mi)	23.6	35.6	49.7	64.5	79.8	98.0	133.0	189.6
2020 mean CLIPER5 error (n mi)	45.6	97.9	155.7	208.2	257.0	300.0	366.0	435.0
2020 mean OFCL skill relative to CLIPER5 (%)	48.2	63.6	68.1	69.0	68.9	67.3	63.7	56.4
2020 mean OFCL bias vector (°/n mi)	354/003	319/004	300/006	305/008	304/010	315/010	177/008	172/048
2020 number of cases	535	474	419	369	319	275	192	131
2015-2019 mean OFCL error (n mi)	24.2	37.1	49.8	65.3		96.5	133.2	171.6
2015-2019 mean CLIPER5 error (n mi)	44.8	96.4	156.9	218.4		331.3	431.5	511.9
2015-2019 mean OFCL skill relative to CLIPER5 (%)	46.0	61.5	68.3	70.1		70.9	69.1	66.5
2015-2019 mean OFCL bias vector (°/n mi)	356/002	315/003	301/004	301/004		266/002	266/007	263/030
2015-2019 number of cases	1437	1288	1145	1010	0	776	602	474
2020 OFCL error relative to 2015-2019 mean (%)	-2.5	-4.0	-0.2	-1.2		1.6	-0.2	10.5
2020 CLIPER5 error relative to 2015-2019 mean (%)	1.8	1.6	-0.8	-4.7		-9.4	-15.2	-15.0

Table 3a. Homogenous comparison of Atlantic basin early track guidance model errors (n mi) for 2020. Errors smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	21.0	32.2	46.9	60.7	78.3	96.8	141.2	217.2
OCD5	44.0	101.1	165.4	220.8	269.7	310.4	357.3	404.2
GFSI	22.1	37.2	50.3	65.3	84.3	107.4	172.6	281.6
HMNI	24.4	38.2	54.2	71.8	93.9	124.1	177.1	245.9
HWFI	25.1	41.4	57.6	76.4	98.2	122.7	172.4	275.3
EGRI	25.1	41.8	59.9	77.5	100.7	129.0	200.5	300.2
EMXI	22.6	36.4	53.1	70.4	90.4	111.1	164.8	262.7
CMCI	26.8	44.1	61.6	77.4	95.9	117.5	166.3	250.9
NVGI	28.4	47.3	68.6	88.5	112.6	131.8	186.2	262.3
CTCI	22.5	36.0	51.5	68.0	86.9	110.6	163.1	242.0
AEMI	22.6	37.3	53.5	69.5	89.0	113.5	167.9	259.7
HCCA	**20.0**	**30.2**	**42.5**	**57.6**	**76.8**	99.5	**141.1**	**215.7**
TVCA	**20.4**	**31.2**	**45.0**	**59.7**	**76.3**	**96.4**	**140.4**	224.0
FSSE	21.1	32.3	47.5	62.3	80.2	101.2	143.2	**213.6**
Forecasts	310	280	246	210	171	143	89	52

Table 3b. Homogenous comparison of Atlantic basin early track guidance model bias vectors (º/n mi) for 2020.

		Forecast Period (h)						
Model ID	12	24	36	48	60	72	96	120
OFCL	296/001	249/004	243/007	245/010	225/013	211/016	191/040	167/087
OCD5	162/004	157/015	149/026	126/046	116/081	119/114	120/186	127/265
GFSI	312/002	256/003	237/004	229/007	198/015	191/021	175/047	169/117
HMNI	359/005	353/008	337/009	322/009	285/007	264/013	214/012	126/042
HWFI	355/006	330/009	304/013	295/018	276/024	263/035	239/041	201/068
EGRI	199/005	190/009	188/015	191/020	181/025	171/036	159/076	136/168
EMXI	249/004	233/011	233/017	234/025	229/025	224/037	213/057	191/086
CMCI	266/005	263/010	272/013	269/013	229/008	179/015	125/051	118/108
NVGI	257/001	104/003	111/005	115/011	114/022	118/031	137/061	122/122
CTCI	033/004	046/007	045/008	048/008	109/009	125/013	137/032	128/087
AEMI	240/003	229/008	233/012	235/015	221/018	210/021	171/042	144/104
HCCA	217/002	215/005	228/009	242/01	241/020	239/024	215/034	170/056
TVCA	295/002	245/004	238/007	238/011	218/037	218/017	210/023	188/045
FSSE	316/001	266/002	261/004	276/008	279/009	280/008	175/012	133/054
Forecasts	310	280	246	210	171	143	89	52

Table 4. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the Atlantic basin for the 2020 season for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
2020 mean OFCL error (kt)	5.6	8.6	10.1	11.6	11.5	10.9	11.9	13.1
2020 mean Decay-SHIFOR5 error (kt)	7.3	11.2	14.8	17.0	17.5	18.7	21.1	19.7
2020 mean OFCL skill relative to Decay-SHIFOR5 (%)	23.3	23.2	31.8	31.8	34.3	41.7	43.6	33.5
2020 OFCL bias (kt)	0.5	0.4	0.6	0.8	1.5	2.2	0.7	-3.2
2020 number of cases	535	474	419	369	319	275	192	131
2015-19 mean OFCL error (kt)	5.2	7.7	9.5	10.7		13.0	14.4	15.5
2015-19 mean Decay-SHIFOR5 error (kt)	6.9	10.8	14.1	17.0		20.6	22.5	24.6
2015-19 mean OFCL skill relative to Decay-SHIFOR5 (%)	24.6	28.7	32.6	37.1		36.9	36.0	37.0
2015-19 OFCL bias (kt)	-0.6	-0.9	-1.3	-1.7		-1.6	-1.8	-3.2
2015-19 number of cases	1437	1288	1145	1010	0	776	602	474
2020 OFCL error relative to 2015-19 mean (%)	7.7	11.7	6.3	8.4		-16.2	-17.4	-15.5
2020 Decay-SHIFOR5 error relative to 2015-19 mean (%)	5.8	3.7	5.0	0.0		-9.2	-6.2	-19.9

Table 5a. Homogenous comparison of selected Atlantic basin early intensity guidance model errors (kt) for 2020. Errors smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	6.3	9.2	10.7	11.7	12.0	10.6	12.5	14.7
OCD5	8.2	12.2	15.6	17.2	17.7	18.2	20.1	17.9
HWFI	7.2	9.6	10.8	11.7	13.0	13.9	14.0	**13.2**
HMNI	7.9	11.5	13.2	14.1	14.7	14.5	16.0	16.1
CTCI	7.4	10.1	11.3	11.7	13.4	15.5	15.4	16.9
DSHP	7.3	9.7	11.9	13.8	14.6	13.9	18.3	19.8
LGEM	7.3	10.2	12.7	14.3	14.2	13.9	17.1	19.0
IVCN	6.7	**9.0**	**10.3**	**10.8**	**11.4**	11.0	12.8	**13.2**
FSSE	6.7	**8.8**	**10.4**	**11.0**	**11.8**	12.6	17.9	20.1
HCCA	6.6	**9.1**	**10.5**	**10.8**	**11.5**	11.1	12.7	**11.4**
GFSI	8.5	11.6	13.2	13.3	14.5	14.7	16.2	18.1
EMXI	8.8	12.4	13.8	14.8	15.9	16.5	18.0	22.7
NNIC	6.9	**8.9**	**10.0**	**11.0**	12.8	12.3	14.9	16.2
Forecasts	361	321	279	236	197	167	108	69

Table 5b. Homogenous comparison of selected Atlantic basin early intensity guidance model biases (kt) for 2020. Biases smaller than the NHC official forecast are shown in boldface.

		Forecast Period (h)						
Model ID	12	24	36	48	60	72	96	120
OFCL	1.2	1.2	1.6	1.6	2.0	2.4	1.4	-4.4
OCD5	**-0.6**	-1.8	-2.7	-3.7	-3.9	-4.3	-7.5	-10.2
HWFI	-1.8	-2.4	-2.2	-1.7	**-0.6**	**0.5**	**-0.9**	-5.2
HMNI	**0.0**	-1.4	-2.1	-2.1	**-0.6**	**0.7**	**0.3**	-5.7
CTCI	**-1.0**	-2.2	-2.0	**-1.1**	**-0.6**	**-1.1**	-2.0	-4.4
DSHP	**-1.0**	-2.0	-2.1	-2.4	-2.6	-2.6	-4.9	-8.5
LGEM	-1.3	-3.0	-3.4	-3.9	-3.8	-3.8	-5.7	-9.7
IVCN	**-0.7**	-1.9	-2.1	-2.0	**-1.3**	**-1.0**	-2.4	-6.7
FSSE	**0.2**	**0.4**	**1.1**	2.0	3.1	4.4	3.9	**-2.2**
HCCA	**-0.6**	-1.3	**-1.1**	**0.5**	**1.8**	2.7	2.6	**0.0**
GFSI	**-0.8**	-2.3	-3.7	-4.7	-5.2	-5.3	-7.2	-13.5
EMXI	-1.6	-3.0	-4.6	-7.1	-10.0	-11.6	-15.2	-19.5
NNIC	**0.8**	1.2	**1.4**	2.1	3.7	3.0	**-1.2**	**2.2**
Forecasts	361	321	279	236	197	167	108	69

Table 6. Official Atlantic track and intensity forecast verifications (OFCL) for 2020 by storm. CLIPER5 (CLP5) and SHIFOR5 (SHF5) forecast errors are given for comparison and indicated collectively as OCD5. The number of track and intensity forecasts are given by NT and NI, respectively. Units for track and intensity errors are n mi and kt, respectively.

Verification statistics for: AL012020 ARTHUR

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	11	5.5	5.9	11	0.9	1.8
012	9	17.4	51.3	9	1.1	5.4
024	7	24.6	95.8	7	3.6	10.1
036	5	17.4	107.6	5	0.0	13.6
048	3	17.6	71.9	3	1.7	17.7
060	1	46.8	57.1	1	0.0	20.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL022020 BERTHA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	4	18.6	29.8	4	0.0	2.5
012	2	34.4	86.5	2	2.5	6.5
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL032020 CRISTOBAL

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	28	8.6	9.1	28	2.1	2.1
012	28	19.5	48.4	28	4.5	5.7
024	28	30.7	113.3	28	5.5	8.6
036	27	44.7	181.1	27	4.8	10.4
048	25	57.4	234.0	25	4.6	10.6
060	23	65.6	282.0	23	5.0	8.9
072	21	70.9	325.5	21	6.7	7.3
096	17	102.0	372.6	17	5.6	9.5
120	13	145.2	387.1	13	8.8	13.9

Verification statistics for: AL042020 DOLLY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	1.5	1.5	6	2.5	2.5
012	4	21.5	35.7	4	5.0	5.5
024	2	28.7	66.5	2	7.5	4.5
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL052020 EDOUARD

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	10	1.1	1.1	10	0.0	0.0
012	8	29.5	78.1	8	2.5	2.2
024	6	44.9	213.1	6	3.3	3.5
036	4	63.6	348.5	4	2.5	1.8
048	2	85.1	455.5	2	5.0	1.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL062020 FAY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	2.0	2.0	6	0.8	0.8
012	4	12.8	39.9	4	5.0	5.8
024	2	13.9	110.2	2	7.5	11.5
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL072020 GONZALO

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	17	5.5	6.3	17	0.3	0.6
012	15	26.9	36.7	15	7.0	6.7
024	13	49.2	68.3	13	15.8	12.8
036	11	64.1	109.9	11	22.7	20.1
048	9	70.0	138.9	9	24.4	22.9
060	7	79.6	179.3	7	24.3	22.6
072	5	85.4	233.1	5	23.0	17.8
096	1	96.8	422.8	1	20.0	14.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL082020 HANNA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	16	9.2	8.3	16	3.1	3.4
012	14	20.9	29.4	14	5.4	5.4
024	12	21.1	61.1	12	8.8	10.1
036	10	31.4	110.2	10	13.5	13.3
048	8	50.3	192.8	8	19.4	13.2
060	6	67.4	295.2	6	21.7	17.0
072	4	105.7	399.9	4	17.5	21.5
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL092020 ISAIAS

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	24	3.8	3.8	24	2.1	2.3
012	22	22.1	44.0	22	7.5	9.0
024	20	36.0	91.4	20	11.0	12.9
036	18	54.7	125.8	18	11.4	16.1
048	16	73.4	157.3	16	11.2	16.5
060	14	82.2	179.6	14	7.9	13.4
072	12	97.7	183.2	12	7.1	12.4
096	8	124.0	242.4	8	3.8	16.5
120	4	183.1	405.5	4	8.8	13.0

Verification statistics for: AL102020 TEN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	5	11.6	11.6	5	0.0	0.0
012	3	20.9	43.6	3	3.3	4.3
024	1	32.1	123.0	1	5.0	8.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL112020 JOSEPHINE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	20	8.7	8.7	20	1.5	1.5
012	18	29.4	36.5	18	4.4	6.9
024	16	33.8	56.7	16	5.9	8.4
036	14	41.2	83.2	14	7.1	9.4
048	12	43.5	94.9	12	9.2	12.2
060	10	65.3	128.6	10	11.0	17.2
072	8	78.0	148.8	8	8.8	17.4
096	4	93.0	110.7	4	7.5	26.5
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL122020 KYLE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	5	2.5	2.5	5	2.0	4.0
012	3	27.8	41.4	3	3.3	4.7
024	1	45.9	107.9	1	5.0	9.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL132020 LAURA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	37	10.4	10.7	37	1.1	1.2
012	35	26.3	46.5	35	4.1	7.6
024	33	39.5	89.8	33	7.3	12.0
036	31	56.1	151.5	31	8.2	14.9
048	29	69.4	238.6	29	8.6	18.1
060	27	79.3	314.1	27	10.6	21.4
072	25	91.1	378.2	25	10.4	26.8
096	21	120.3	549.2	21	13.6	36.9
120	17	182.3	735.0	17	21.2	29.8

Verification statistics for: AL142020 MARCO

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	16	5.7	5.7	16	1.2	1.2
012	14	30.3	39.7	14	7.1	8.4
024	12	54.1	74.7	12	13.3	13.9
036	10	84.1	125.7	10	15.0	21.2
048	8	129.0	193.8	8	15.0	26.5
060	6	184.0	271.3	6	13.3	25.0
072	4	225.2	361.7	4	21.2	17.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL152020 OMAR

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	20	4.4	4.4	20	1.2	1.5
012	18	19.2	44.1	18	1.4	3.5
024	16	32.5	103.6	16	3.8	7.4
036	14	49.3	175.5	14	3.2	14.4
048	12	72.4	253.6	12	5.0	21.7
060	10	86.1	313.6	10	4.5	28.2
072	8	121.4	383.0	8	5.0	33.2
096	4	249.0	381.8	4	3.8	35.8
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL162020 NANA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	10	1.4	3.2	10	2.0	2.0
012	8	24.8	25.6	8	5.6	6.8
024	6	45.6	65.4	6	7.5	5.0
036	4	67.4	134.7	4	10.0	7.5
048	2	104.1	231.0	2	17.5	16.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL172020 PAULETTE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	40	6.7	6.7	40	0.6	0.6
012	36	18.0	42.5	36	4.3	4.1
024	34	33.7	100.5	34	6.9	6.0
036	32	49.8	167.1	32	7.8	8.3
048	30	68.7	212.2	30	7.7	9.3
060	28	95.4	248.5	28	7.3	9.4
072	26	132.7	270.9	26	8.3	10.7
096	22	212.4	327.3	22	12.5	11.4
120	21	277.4	536.5	21	15.5	15.9

Verification statistics for: AL182020 RENE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	30	8.0	7.9	30	1.3	1.3
012	28	15.3	26.4	28	3.9	4.5
024	26	26.6	62.3	26	9.6	6.9
036	24	37.0	93.9	24	16.5	11.7
048	22	52.8	119.2	22	23.4	15.1
060	20	77.5	135.5	20	28.5	18.5
072	18	105.6	139.6	18	29.4	21.8
096	14	145.3	170.8	14	27.1	30.3
120	10	237.1	253.5	10	24.5	27.2

Verification statistics for: AL192020 SALLY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	23	8.1	8.1	23	2.4	2.6
012	21	20.9	30.8	21	8.1	10.9
024	19	36.3	60.7	19	7.6	11.2
036	17	51.1	97.2	17	7.4	16.6
048	15	64.8	134.5	15	9.7	25.5
060	13	73.2	167.8	13	15.0	28.6
072	11	87.8	211.2	11	16.4	32.6
096	7	105.9	262.1	7	16.4	35.6
120	3	212.8	395.8	3	16.7	14.3

Verification statistics for: AL202020 TEDDY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	42	7.5	7.6	42	3.5	3.6
012	40	28.5	53.3	40	7.2	9.0
024	38	41.5	107.7	38	9.3	12.1
036	36	50.2	142.3	36	8.1	13.6
048	34	56.4	161.0	34	10.0	15.8
060	32	68.2	169.2	32	9.8	17.5
072	30	81.5	185.6	30	8.0	20.2
096	26	103.3	229.8	26	8.3	22.6
120	22	128.4	234.2	22	10.5	21.6

Verification statistics for: AL212020 VICKY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	15	8.7	8.7	15	1.3	1.7
012	13	26.2	41.9	13	5.0	5.3
024	11	26.6	73.0	11	5.5	8.4
036	9	42.0	145.3	9	7.8	13.8
048	7	61.4	207.3	7	5.7	17.9
060	5	86.2	264.5	5	8.0	20.6
072	3	102.6	334.2	3	6.7	24.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL222020 BETA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	21	5.1	6.7	21	1.0	1.0
012	19	24.1	41.7	19	4.2	6.3
024	17	36.7	81.7	17	5.0	9.4
036	15	45.7	128.6	15	6.0	11.2
048	13	50.8	188.9	13	12.3	9.5
060	11	53.6	258.4	11	16.4	10.5
072	9	60.3	324.1	9	20.0	11.2
096	5	108.3	364.9	5	22.0	4.6
120	1	199.1	348.1	1	25.0	3.0

Verification statistics for: AL232020 WILFRED

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	11	8.2	8.2	11	0.0	0.0
012	9	34.1	44.9	9	3.3	3.0
024	7	47.3	77.2	7	4.3	7.6
036	5	44.1	64.5	5	5.0	12.4
048	3	42.5	64.0	3	5.0	18.3
060	1	87.7	172.9	1	0.0	21.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL242020 ALPHA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	3	4.0	4.0	3	3.3	3.3
012	1	54.2	31.9	1	0.0	1.0
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL252020 GAMMA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	15	3.3	3.3	15	1.3	1.3
012	15	25.5	42.0	15	5.3	9.3
024	13	45.7	94.2	13	9.2	14.6
036	11	64.1	144.7	11	10.5	18.3
048	9	79.1	164.0	9	11.7	18.0
060	7	86.1	154.9	7	12.9	13.6
072	5	96.1	140.2	5	16.0	10.0
096	1	124.3	266.4	1	20.0	20.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL262020 DELTA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	24	7.2	7.5	24	2.9	2.7
012	22	21.3	45.8	22	11.8	14.7
024	20	32.4	113.5	20	16.8	21.8
036	18	49.2	188.8	18	19.4	28.3
048	16	66.3	261.0	16	17.5	29.7
060	14	89.5	322.1	14	10.4	26.6
072	12	114.9	393.5	12	8.3	29.4
096	8	150.6	495.8	8	18.8	36.4
120	4	170.8	534.0	4	3.8	20.8

Verification statistics for: AL272020 EPSILON

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	28	9.1	9.3	28	1.4	1.6
012	26	26.7	69.6	26	7.1	7.5
024	24	30.8	135.2	24	9.8	11.5
036	22	38.5	208.4	22	11.8	14.6
048	20	41.6	253.8	20	12.5	15.2
060	18	48.9	314.8	18	10.8	15.1
072	16	61.6	380.6	16	6.2	13.1
096	12	120.2	510.2	12	4.2	14.1
120	8	245.4	440.7	8	5.6	10.6

Verification statistics for: AL282020 ZETA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	20	7.6	6.5	20	3.0	3.2
012	18	19.5	70.1	18	7.5	8.7
024	16	25.0	171.5	16	11.6	14.2
036	14	39.8	280.2	14	12.1	16.4
048	12	63.1	368.4	12	12.1	19.2
060	10	85.8	452.0	10	11.5	12.3
072	8	101.8	527.6	8	16.2	14.1
096	4	75.1	610.5	4	32.5	29.5
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL292020 ETA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	47	6.3	6.3	47	0.6	0.7
012	43	25.7	59.4	43	5.8	8.9
024	39	42.3	147.1	39	10.9	16.5
036	37	64.4	242.2	37	13.8	21.1
048	35	91.0	327.0	35	14.7	19.7
060	33	104.8	385.8	33	9.8	15.8
072	31	124.1	413.3	31	6.3	13.3
096	27	142.4	426.6	27	8.3	15.8
120	25	172.4	403.1	25	9.0	18.6

Verification statistics for: AL302020 THETA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	22	6.7	6.7	22	2.3	2.3
012	20	24.9	37.2	20	5.2	5.8
024	18	34.5	68.3	18	5.8	5.7
036	16	46.1	131.5	16	7.8	5.4
048	14	51.5	189.2	14	6.4	5.4
060	12	59.7	268.4	12	5.4	4.8
072	10	76.3	345.1	10	5.5	6.2
096	6	114.5	496.6	6	10.0	15.3
120	2	121.8	629.6	2	15.0	15.5

Verification statistics for: AL312020 IOTA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	21	7.1	7.3	21	2.9	2.6
012	19	23.3	34.5	19	6.6	9.1
024	17	30.8	57.8	17	7.4	18.2
036	15	39.8	81.4	15	9.0	25.5
048	13	54.5	124.7	13	13.5	32.8
060	11	72.0	186.5	11	15.5	44.8
072	9	88.2	244.5	9	12.2	54.2
096	5	109.2	311.9	5	13.0	11.4
120	1	72.5	349.7	1	0.0	32.0

Table 7. Homogenous comparison of official and CLIPER5 track forecast errors in the eastern North Pacific basin in 2020 for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
2020 mean OFCL error (n mi)	23.9	35.6	46.2	57.5	68.2	81.7	110.9	148.2
2020 mean CLIPER5 error (n mi)	38.4	75.8	116.3	161.7	202.3	244.4	325.0	401.7
2020 mean OFCL skill relative to CLIPER5 (%)	37.8	53.0	60.3	64.4	66.3	66.6	65.9	63.0
2020 mean OFCL bias vector (°/n mi)	090/001	097/003	226/002	211/007	204/011	202/019	171/034	156/054
2020 number of cases	217	178	149	125	103	83	49	29
2015-2019 mean OFCL error (n mi)	21.8	34.0	44.9	55.3		77.1	99.1	123.2
2015-2019 mean CLIPER5 error (n mi)	34.3	69.8	108.7	146.7		215.9	268.7	328.2
2015-2019 mean OFCL skill relative to CLIPER5 (%)	36.4	51.3	58.7	62.3		64.3	71.3	69.8
2015-2019 mean OFCL bias vector (°/n mi)	339/002	351/003	002/003	009/005		258/008	027/009	038/013
2015-2019 number of cases	1639	1463	1301	1156	0	913	714	553
2020 OFCL error relative to 2015-2019 mean (%)	9.6	4.7	2.9	4.0		6.0	11.9	20.3
2020 CLIPER5 error relative to 2015-2019 mean (%)	12.0	8.6	7.0	10.2		13.2	-9.0	-1.0

Table 8a. Homogenous comparison of eastern North Pacific basin early track guidance model errors (n mi) for 2020. Errors smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	23.2	35.2	47.1	60.6	72.1	82.9	111.6	138.0
OCD5	35.2	71.6	111.2	150.8	183.5	215.3	265.6	326.6
GFSI	25.7	41.2	55.3	71.3	79.5	86.9	114.8	183.9
HWFI	26.4	43.0	59.5	80.3	96.0	108.8	161.6	237.8
HMNI	24.0	38.9	51.9	69.2	87.3	103.0	147.3	203.4
EMXI	25.5	39.8	52.2	63.9	76.7	91.6	136.6	**137.1**
EGRI	23.4	38.5	56.5	75.8	93.9	108.0	129.3	183.4
CMCI	25.9	42.9	58.3	72.6	88.7	104.1	136.6	199.3
NVGI	29.6	47.3	65.4	83.4	101.5	121.9	141.9	210.8
AEMI	25.9	40.9	54.4	68.1	75.3	85.4	116.6	177.9
FSSE	23.3	35.8	49.6	62.2	73.8	83.5	116.4	139.3
TVCE	**22.3**	**34.4**	**46.3**	61.5	74.8	86.2	116.3	145.9
HCCA	**22.6**	**34.1**	**45.7**	**59.3**	**69.4**	**78.9**	114.6	145.3
Forecasts	140	120	102	85	70	54	30	19

Table 8b. Homogenous comparison of eastern North Pacific basin early track guidance model bias vectors (º/n mi) for 2020.

		Forecast Period (h)						
Model ID	12	24	36	48	60	72	96	120
OFCL	324/003	298/003	276/007	248/012	237/015	232/020	193/028	151/059
OCD5	107/001	145/007	178/013	184/024	184/041	178/068	159/185	138/284
GFSI	015/007	027/011	030/014	040/012	066/016	082/022	101/057	109/110
HWFI	240/002	169/005	191/007	209/014	199/018	173/025	120/054	115/149
HMNI	280/003	212/001	289/003	265/011	259/015	265/016	292/017	110/029
EMXI	298/008	278/012	259/023	245/023	237/039	238/051	241/078	228/068
EGRI	292/005	281/010	277/020	273/030	271/039	266/048	240/074	222/123
CMCI	068/006	081/016	070/023	069/021	077/022	082/017	199/019	201/094
NVGI	011/007	018/006	017/007	009/012	012/028	356/042	002/065	039/141
AEMI	028/006	044/011	047/013	065/010	089/014	096/019	097/039	111/070
FSSE	314/004	122/003	152/005	201/010	197/014	196/017	180/030	151/061
TVCE	321/004	318/004	285/007	262/013	252/016	244/019	207/026	158/057
HCCA	327/003	298/003	274/007	255/013	247/015	240/018	204/025	149/066
Forecasts	140	120	102	85	70	54	30	19

Table 9. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the eastern North Pacific basin for the 2020 season for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

		Forecast Period (h)						
	12	24	36	48	60	72	96	120
2020 mean OFCL error (kt)	5.0	6.6	7.9	11.0	13.8	17.2	17.9	16.0
2020 mean Decay-SHIFOR5 error (kt)	6.0	9.7	12.6	15.7	18.5	19.3	18.6	14.0
2020 mean OFCL skill relative to Decay-SHIFOR5 (%)	16.7	32.0	37.3	29.9	25.4	10.9	3.8	-14.3
2020 OFCL bias (kt)	1.3	2.2	3.6	4.3	4.5	3.7	-0.9	-7.1
2020 number of cases	217	178	149	125	103	83	49	29
2015-19 mean OFCL error (kt)	6.0	9.9	12.1	13.5		15.4	15.6	16.4
2015-19 mean Decay-SHIFOR5 error (kt)	7.8	13.1	16.6	18.9		21.4	22.6	22.4
2015-19 mean OFCL skill relative to Decay-SHIFOR5 (%)	23.1	24.4	27.1	28.6		28.0	31.0	26.8
2015-19 OFCL bias (kt)	-0.5	-0.9	-1.5	-2.0		3.0	-1.8	-2.0
2015-19 number of cases	1639	1463	1301	1156	0	913	714	553
2020 OFCL error relative to 2015-19 mean (%)	-16.7	-33.3	-34.7	-18.5		11.7	14.7	-2.4
2020 Decay-SHIFOR5 error relative to 2015-19 mean (%)	-23.1	-26.0	-24.1	-16.9		-9.8	-17.7	-37.5

Table 10a. Homogenous comparison of eastern North Pacific basin early intensity guidance model errors (kt) for 2020. Errors smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	5.5	7.3	8.9	12.0	14.6	17.0	16.9	13.9
OCD5	6.6	10.9	13.8	16.3	17.5	17.2	16.9	**11.3**
HWFI	5.9	7.9	9.4	**10.5**	**12.2**	**13.2**	**13.7**	17.9
HMNI	6.0	7.9	8.9	**9.9**	**11.5**	**13.9**	**14.9**	**12.5**
DSHP	5.8	8.4	10.5	13.5	16.4	19.1	21.5	19.7
LGEM	5.8	8.5	10.9	13.3	15.8	17.1	20.4	18.9
IVCN	**5.2**	7.3	9.0	**11.0**	**12.9**	**15.1**	17.1	16.7
HCCA	5.6	7.9	9.5	**10.8**	**12.6**	**14.4**	**15.9**	15.4
FSSE	5.7	7.8	9.2	**11.3**	**14.0**	**16.5**	**16.8**	16.1
GFSI	6.2	9.9	12.7	14.8	16.3	17.0	20.1	18.1
EMXI	7.4	12.4	16.0	18.8	19.5	18.8	**16.6**	**12.2**
NNIC	5.7	7.8	9.0	**9.3**	**11.7**	**12.8**	**16.6**	16.1
Forecasts	159	132	114	95	80	64	36	23

Table 10b. Homogenous comparison of eastern North Pacific basin early intensity guidance model biases (kt) for 2020. Biases smaller than the NHC official forecast are shown in boldface.

		Forecast Period (h)						
Model ID	12	24	36	48	60	72	96	120
OFCL	2.1	3.1	4.2	5.4	5.8	5.0	-1.7	-6.5
OCD5	**0.8**	**0.3**	**-1.4**	**-2.5**	**-1.4**	**-1.5**	-5.3	**-1.6**
HWFI	-2.5	-3.6	**-3.8**	**-3.7**	**-3.0**	**-2.2**	-5.4	-7.2
HMNI	**1.2**	**-0.4**	**-2.7**	**-4.0**	**-4.3**	**-3.9**	-10.7	-7.5
DSHP	**0.9**	**1.8**	**2.4**	**4.6**	6.6	7.6	**1.5**	**-4.8**
LGEM	**0.4**	**-1.0**	**-2.2**	**-1.5**	**-0.4**	**0.2**	-6.6	-12.0
IVCN	**0.4**	**-0.3**	**-0.7**	**0.1**	**1.3**	**2.0**	-5.0	-7.6
HCCA	2.1	3.1	**3.2**	**3.8**	**3.7**	**3.4**	-3.7	-6.8
FSSE	2.4	3.5	**3.9**	**5.2**	6.3	7.8	3.8	**2.8**
GFSI	**-0.4**	**-1.7**	**-2.5**	**-1.9**	**-0.8**	**1.0**	2.5	-9.9
EMXI	-2.4	-4.8	-7.3	-9.3	-9.7	-9.6	-12.0	-9.2
NNIC	**1.2**	**1.8**	**2.3**	**2.9**	**3.0**	**1.6**	-6.2	-7.0
Forecasts	159	132	114	95	80	64	36	23

Table 11. Official eastern North Pacific track and intensity forecast verifications (OFCL) for 2020 by storm. CLIPER5 (CLP5) and SHIFOR5 (SHF5) forecast errors are given for comparison and indicated collectively as OCD5. The number of track and intensity forecasts are given by NT and NI, respectively. Units for track and intensity errors are n mi and kt, respectively.

Verification statistics for: EP012020 ONE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	4	3.3	3.3	4	0.0	0.0
012	2	21.3	19.9	2	0.0	1.5
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP022020 AMANDA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	4	9.2	10.6	4	2.5	2.5
012	2	17.8	41.9	2	5.0	5.0
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP032020 BORIS

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	12	8.2	8.2	12	0.4	0.8
012	12	24.1	38.3	12	2.1	3.9
024	10	38.3	64.3	10	3.5	6.0
036	8	51.1	97.8	8	5.0	10.4
048	6	50.5	119.8	6	5.8	11.2
060	4	52.7	150.3	4	3.8	23.5
072	2	74.9	161.9	2	0.0	27.5
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP042020 FOUR

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	3	5.7	5.9	3	1.7	1.7
012	1	29.3	41.0	1	5.0	5.0
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0

096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP052020 CRISTINA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	24	11.2	11.5	24	2.9	2.9
012	22	21.8	35.3	22	5.9	4.7
024	20	29.5	69.0	20	8.0	6.2
036	18	37.7	105.4	18	11.1	7.9
048	16	50.0	144.7	16	15.3	9.3
060	14	62.0	176.6	14	18.2	7.7
072	12	64.4	193.5	12	19.6	8.0
096	8	74.5	211.3	8	20.6	10.0
120	4	48.8	284.2	4	23.8	16.8

Verification statistics for: EP062020 SIX

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	4	7.8	7.8	4	0.0	0.0
012	2	50.3	44.4	2	10.0	6.5
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP072020 SEVEN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	4	3.5	6.7	4	3.8	3.8
012	2	18.8	32.6	2	5.0	4.0
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP082020 DOUGLAS

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	16	2.9	2.9	16	0.9	0.9
012	16	20.8	34.4	16	7.5	9.8
024	16	35.3	84.3	16	8.4	15.9
036	16	47.8	142.9	16	8.1	19.0
048	16	58.8	200.4	16	12.2	24.3
060	16	73.2	260.9	16	18.8	27.5
072	16	90.2	320.3	16	23.1	28.2
096	16	138.8	433.4	16	21.2	22.4
120	14	192.8	565.8	14	20.4	14.5

Verification statistics for: EP092020 ELIDA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	16	6.7	6.7	16	1.2	1.2
012	14	19.7	21.9	14	6.4	8.1
024	12	39.3	48.1	12	7.1	13.0
036	10	61.1	82.3	10	5.0	16.5
048	8	92.4	122.7	8	5.6	18.5
060	6	119.7	172.1	6	10.0	19.5
072	4	140.0	227.8	4	11.2	12.5
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP102020 TEN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	13	5.8	5.8	13	0.0	0.0
012	11	18.2	35.6	11	0.9	4.3
024	9	21.3	83.9	9	1.7	6.7
036	7	26.8	139.6	7	2.1	10.1
048	5	32.6	214.2	5	3.0	12.8
060	3	38.5	277.2	3	1.7	23.3
072	1	50.7	334.6	1	5.0	27.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP112020 FAUSTO

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	17.2	18.3	6	0.8	0.8
012	4	23.6	91.8	4	5.0	5.8
024	2	27.1	180.9	2	5.0	7.5
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP122020 GENEVIEVE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	21	6.8	10.0	21	1.4	1.4
012	19	24.4	46.7	19	9.2	9.9
024	17	41.2	100.3	17	15.9	14.0
036	15	59.2	148.9	15	22.3	16.6
048	13	74.9	188.3	13	27.7	16.9
060	11	82.2	225.0	11	27.7	17.9
072	9	94.1	282.2	9	28.9	15.8
096	5	131.1	371.6	5	23.0	19.4
120	1	183.2	402.9	1	20.0	26.0

Verification statistics for: EP132020 HERNAN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	10	9.3	9.6	10	1.0	1.0
012	8	44.7	58.6	8	4.4	3.4
024	6	57.1	91.3	6	3.3	9.7

036	4	87.0	138.9	4	1.2	13.2
048	2	102.2	189.2	2	0.0	13.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP142020 ISELLE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	17	9.3	9.3	17	0.0	0.0
012	15	24.1	25.4	15	3.3	3.1
024	13	39.1	51.9	13	4.6	6.0
036	11	51.8	79.6	11	4.5	9.8
048	9	55.8	127.6	9	4.4	13.7
060	7	57.3	187.5	7	4.3	19.7
072	5	68.8	261.0	5	6.0	22.0
096	1	89.8	564.3	1	0.0	26.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP152020 JULIO

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	19.5	19.5	6	1.7	1.7
012	4	68.3	90.0	4	7.5	7.2
024	2	122.5	159.2	2	7.5	12.5
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP162020 KARINA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	15	11.8	11.8	15	0.7	0.7
012	13	31.4	43.8	13	4.2	5.1
024	11	38.8	79.2	11	4.5	7.5
036	9	37.3	120.4	9	5.0	4.6
048	7	35.9	127.6	7	4.3	5.4
060	5	53.1	108.5	5	2.0	5.0
072	3	77.5	103.9	3	11.7	7.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP172020 LOWELL

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	20	11.9	11.9	20	1.0	1.0
012	18	18.8	26.7	18	3.6	4.4
024	16	31.0	50.4	16	4.4	5.6
036	14	41.6	75.6	14	5.0	4.0
048	12	54.0	111.0	12	10.4	4.4

060	10	70.2	144.3	10	14.5	4.3
072	8	95.2	188.8	8	18.8	5.8
096	4	132.7	323.6	4	18.8	6.5
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP182020 MARIE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	30	8.3	8.7	30	2.0	2.2
012	28	14.8	32.0	28	3.9	6.2
024	26	23.5	70.0	26	4.2	11.2
036	24	32.0	115.4	24	4.0	16.4
048	22	38.6	154.5	22	6.1	20.1
060	20	47.5	177.1	20	7.8	23.1
072	18	60.2	194.0	18	10.0	24.7
096	14	92.7	224.6	14	11.4	21.0
120	10	122.8	218.9	10	6.5	11.1

Verification statistics for: EP192020 NORBERT

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	14	8.5	8.5	14	3.6	3.6
012	12	34.5	55.2	12	7.1	8.6
024	10	56.3	116.6	10	11.0	13.8
036	9	76.0	185.4	9	13.3	21.9
048	9	89.8	258.3	9	16.1	27.6
060	7	102.7	344.6	7	20.0	30.7
072	5	107.4	421.5	5	23.0	32.0
096	1	44.6	441.0	1	20.0	31.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP202020 ODALYS

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	8	6.8	7.5	8	1.9	1.9
012	6	24.4	53.0	6	5.0	5.3
024	4	25.6	80.2	4	5.0	7.5
036	2	10.8	110.5	2	7.5	4.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP212020 POLO

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	8	3.8	3.8	8	1.2	1.2
012	6	16.4	23.9	6	3.3	6.2
024	4	23.6	49.2	4	3.8	8.2
036	2	18.9	50.8	2	2.5	1.5
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Table 12a. Verification of 48-h probabilistic genesis forecasts for the Atlantic basin in 2020.

Atlantic Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	2	563
10	17	180
20	24	116
30	43	49
40	60	48
50	72	25
60	81	26
70	97	31
80	90	29
90	100	14
100	-	0

Table 12b. Verification of 48-h probabilistic genesis forecasts for the eastern North Pacific basin in 2020.

Eastern North Pacific Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	3	488
10	13	95
20	19	84
30	30	40
40	60	40
50	53	43
60	71	31
70	60	35
80	67	21
90	100	7
100	-	0

Table 13a. Verification of 120-h probabilistic genesis forecasts for the Atlantic basin in 2020.

Atlantic Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	2	154
10	20	290
20	41	186
30	36	122
40	56	82
50	80	44
60	78	55
70	100	46
80	100	47
90	100	55
100	-	0

Table 13b. Verification of 120-h probabilistic genesis forecasts for the eastern North Pacific basin in 2020.

Eastern North Pacific Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	7	119
10	11	166
20	20	139
30	36	112
40	60	57
50	63	43
60	68	65
70	82	83
80	69	49
90	78	51
100		0

Table 14. NHC forecast cone circle radii (n mi) for 2021. Change from 2020 values expressed in n mi and percent are given in parentheses.

Track Forecast Cone Two-Thirds Probability Circles (n mi)		
Forecast Period (h)	**Atlantic Basin**	**Eastern North Pacific Basin**
3	16 (0: 0%)	16 (0: 0%)
12	27 (1: 4%)	25 (0: 0%)
24	40 (-1: -3%)	37 (-1: -3%)
36	55 (0: 0%)	51 (-1: -2%)
48	69 (0: 0%)	64 (-1: -2%)
60	86 (interpolated)	77 (interpolated)
72	102 (-1: -1%)	89 (-2: -2%)
96	148 (-3: -2%)	114 (-1: -1%)
120	200 (4: 2%)	138 (0: 0%)

Table 15. Composition of NHC consensus models for 2021. It is intended that TVCA would be the primary consensus aids for the Atlantic basin and TVCE would be primary for the eastern Pacific.

NHC Consensus Model Definitions For 2021			
Model ID	**Parameter**	**Type**	**Members**
GFEX	Track	Fixed	GFSI EMXI
ICON	Intensity	Fixed	DSHP LGEM HWFI CTCI HMNI
TVCA**	Track	Variable	GFSI EGRI HWFI EMXI CTCI
TVCE	Track	Variable	GFSI EGRI HWFI EMXI CTCI HMNI EMNI
TVDG	Track	Variable	GFSI (double weight) EMXI (double weight) EGRI (double weight) CTCI HWFI
TVCX	Track	Variable	EMXI (double weight) GFSI EGRI HWFI
IVCN	Intensity	Variable	DSHP LGEM HWFI CTCI HMNI
IVDR	Intensity	Variable	CTCI (double weight) HWFI (double weight) HMNI (double weight) GFSI DSHP LGEM

** TVCN will continue to be computed and will have the same composition as TVCA. GPCE circles will continue to be based on TVCN.

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26. As described for Fig. 25, but for 120-h forecasts.

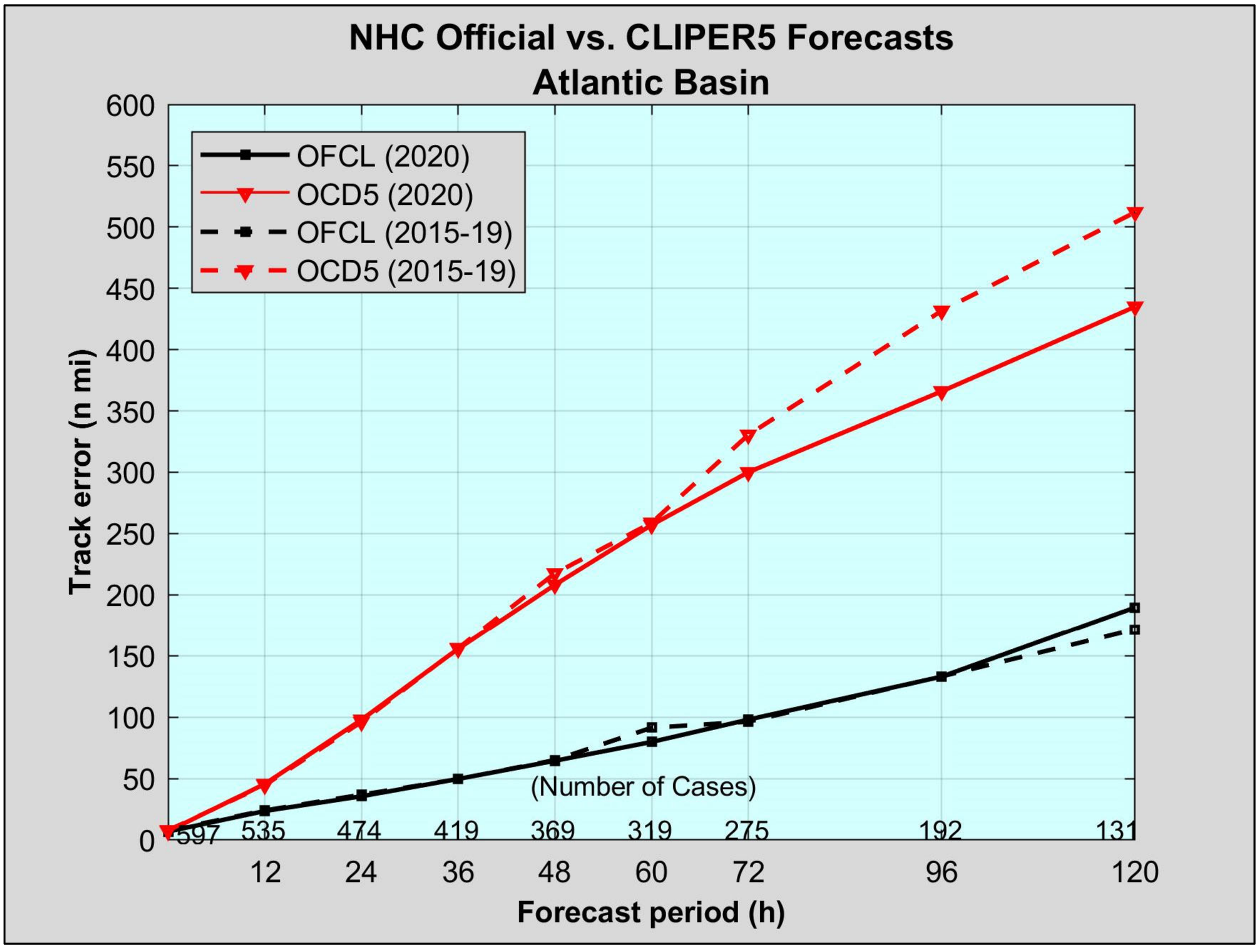
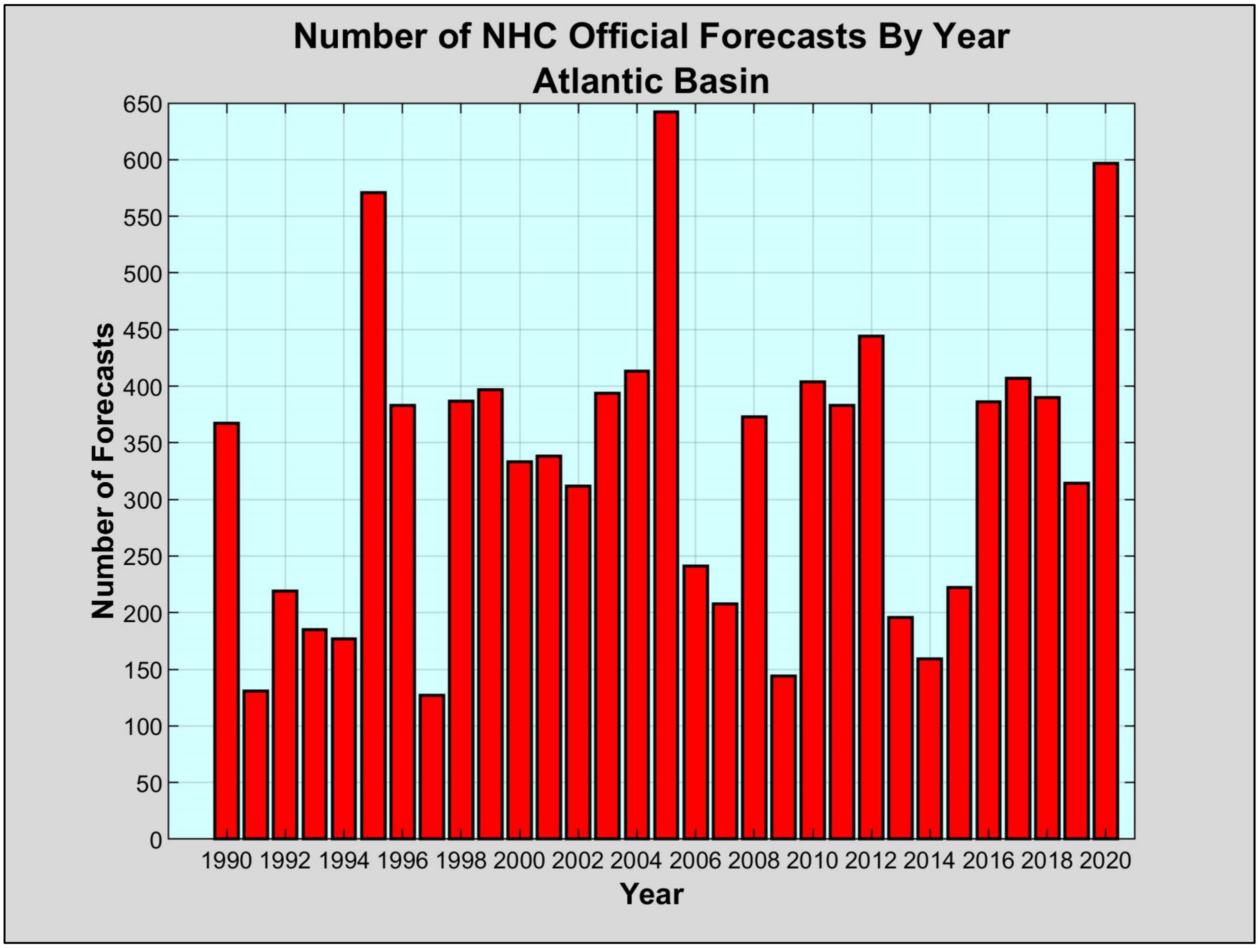


Figure 1. NHC official and CLIPER5 (OCD5) Atlantic basin average track errors for 2020 (solid lines) and 2015-2019 (dashed lines).



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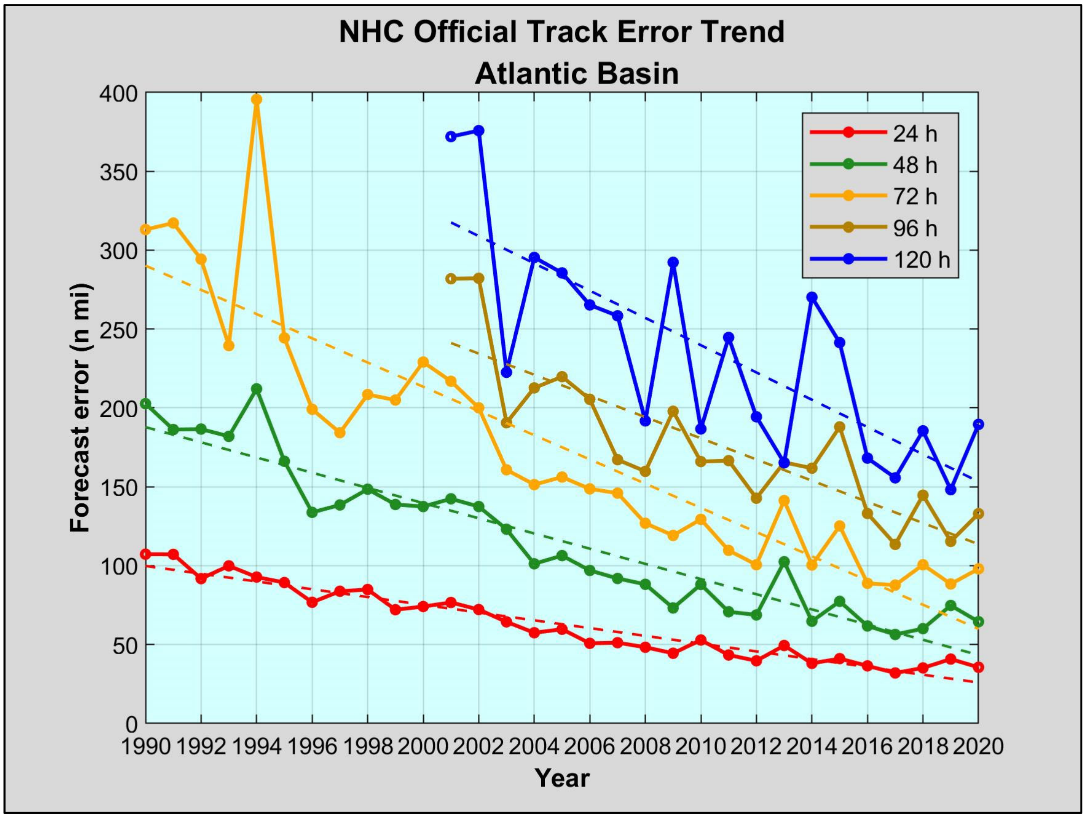


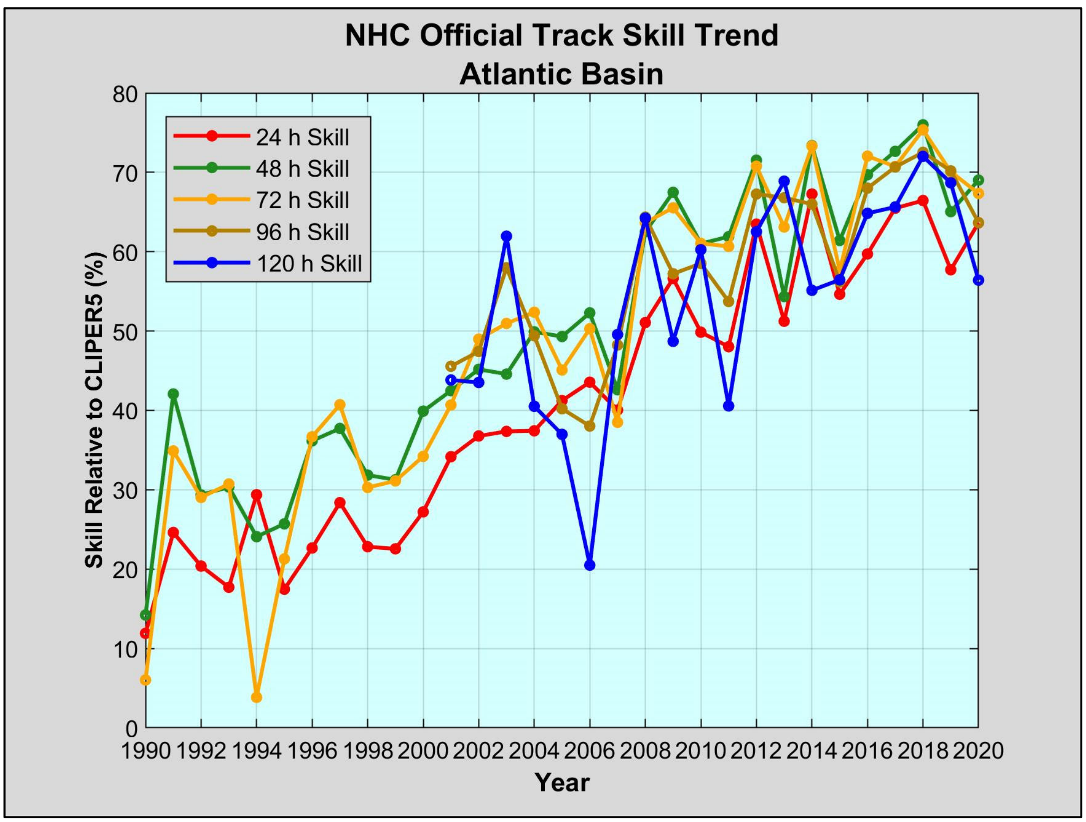
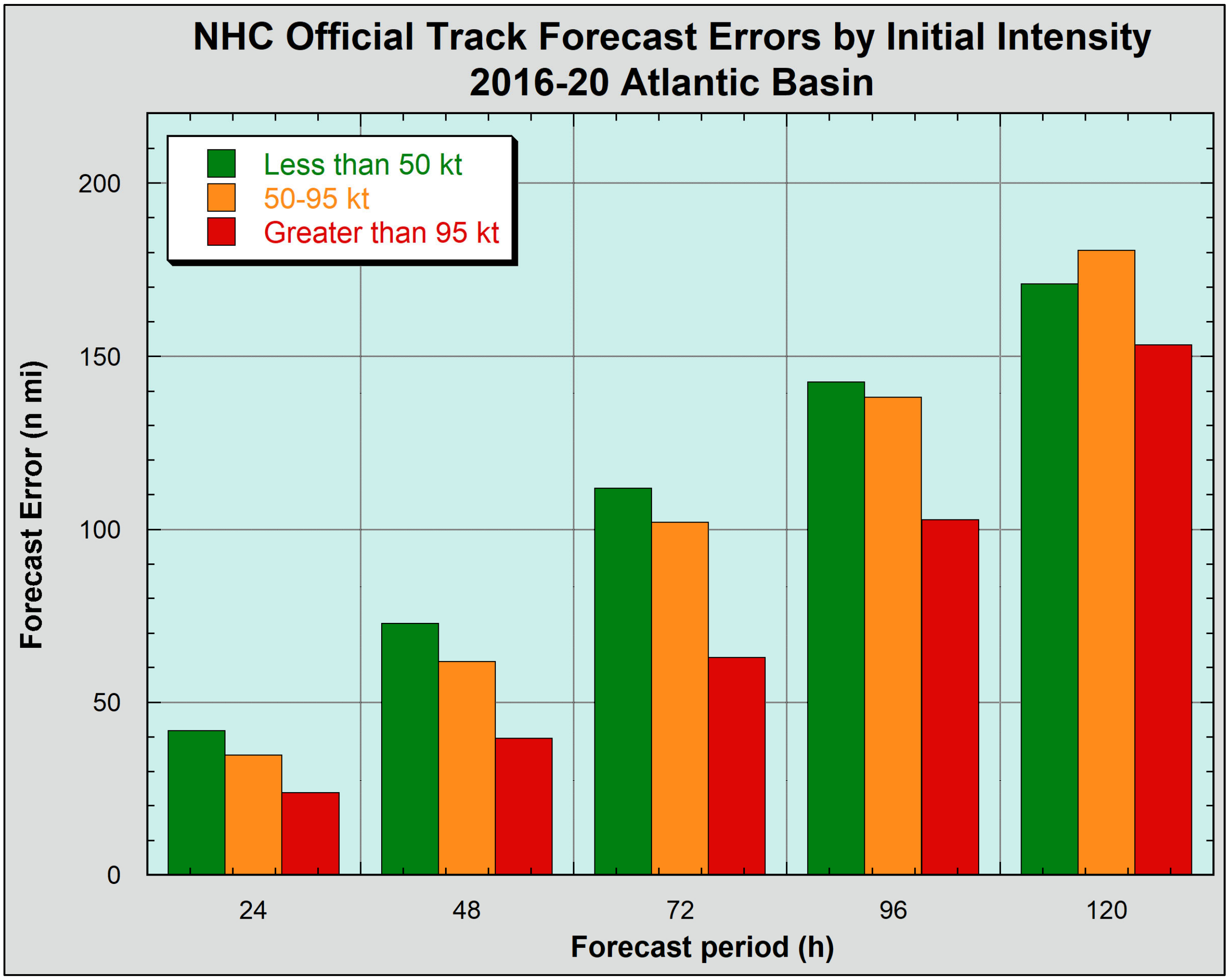


Figure 3. Recent trends in NHC official track forecast error (top) and skill (bottom) for the Atlantic basin.



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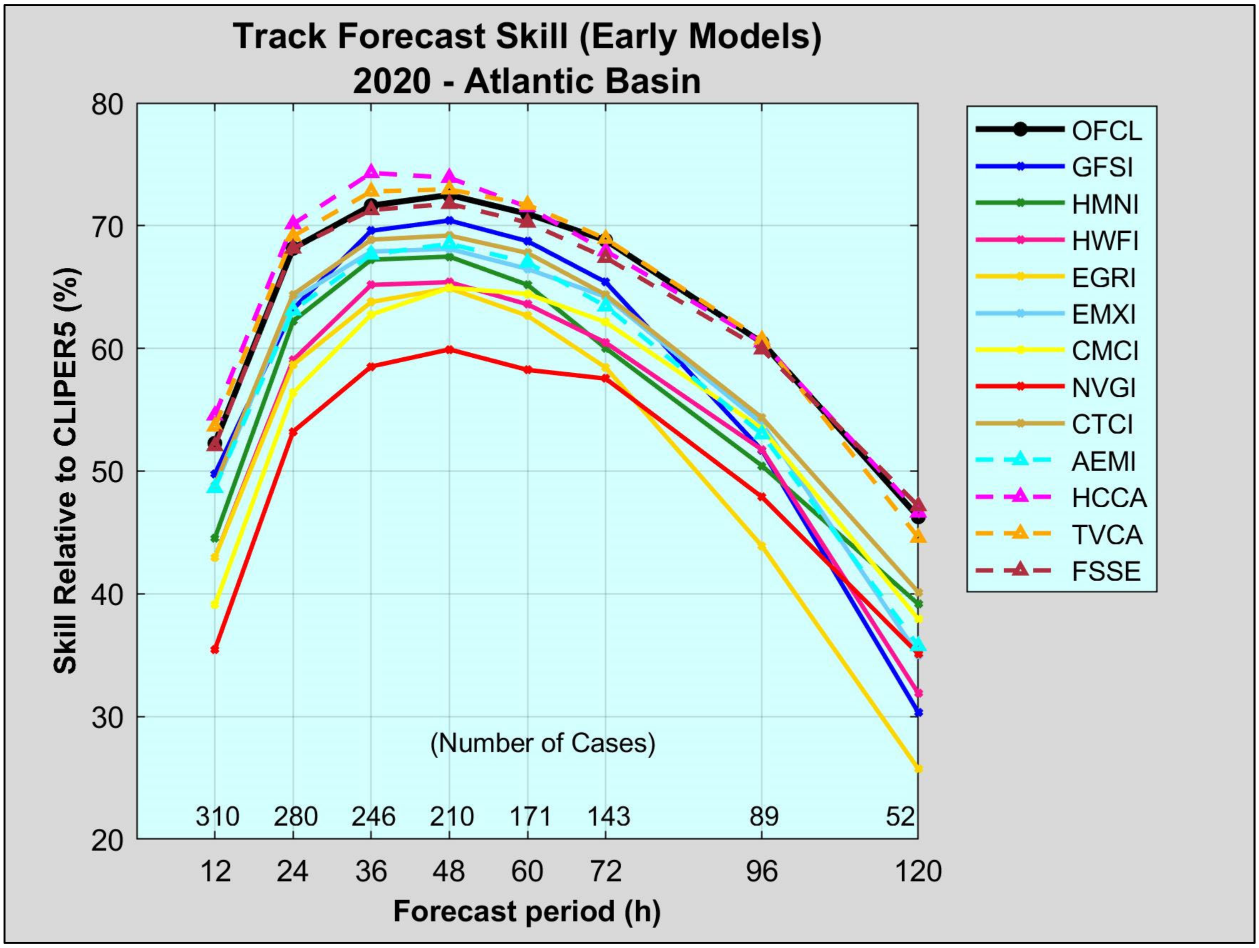
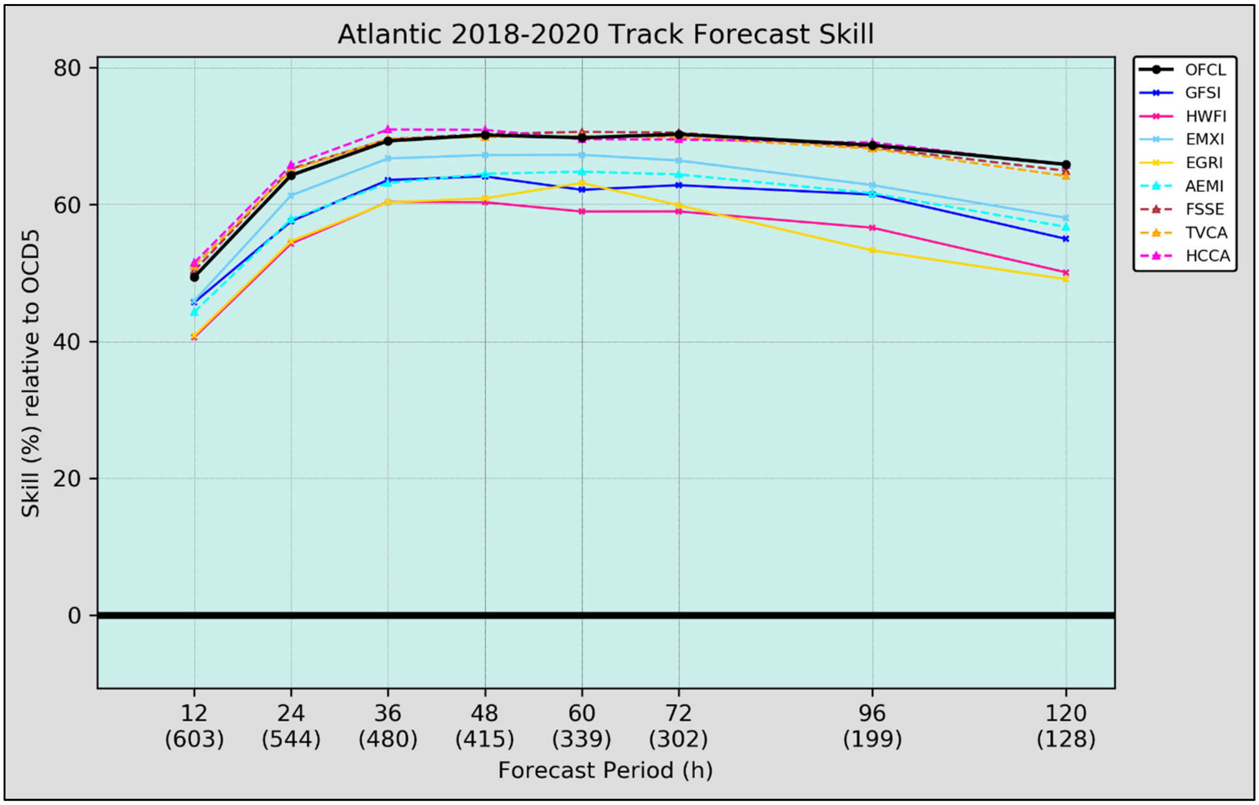


Figure 5. Homogenous comparison for selected Atlantic basin early track models for 2020. This verification includes only those models that were available at least 2/3 of the time (see text).



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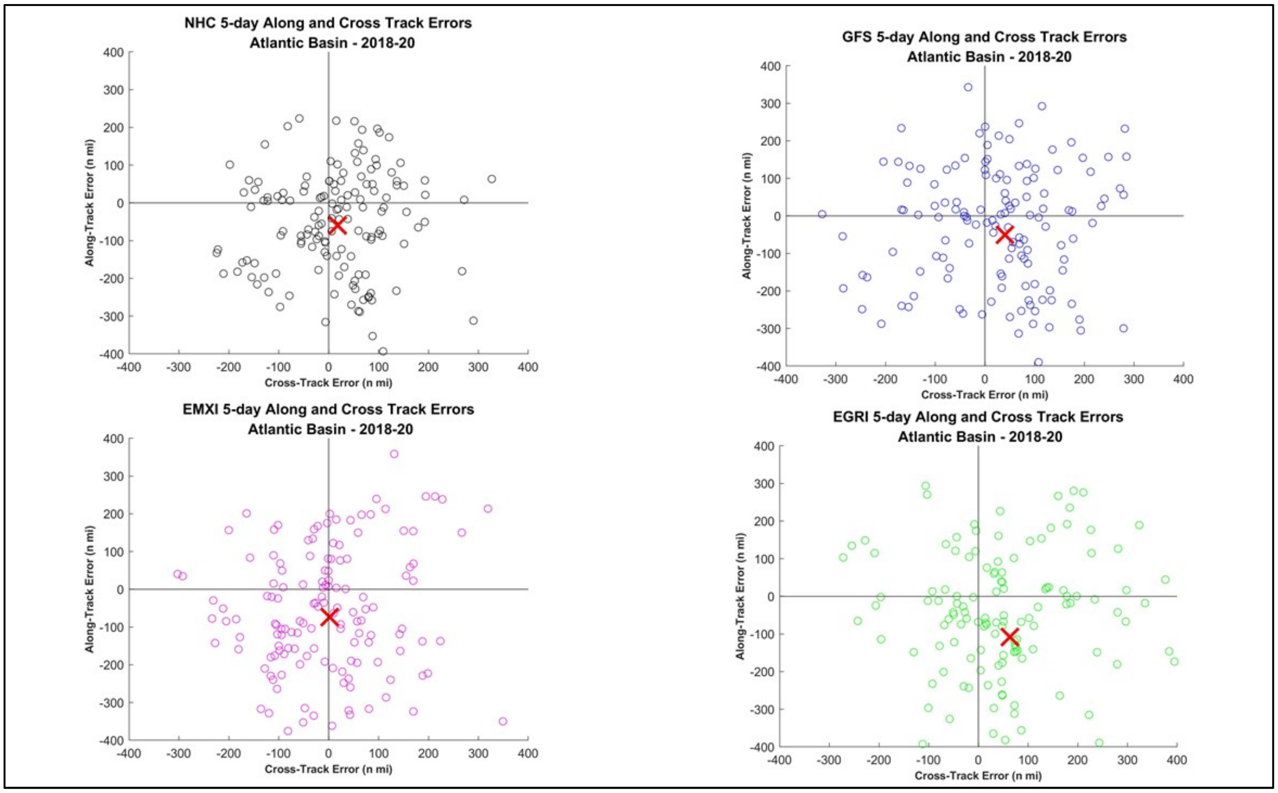
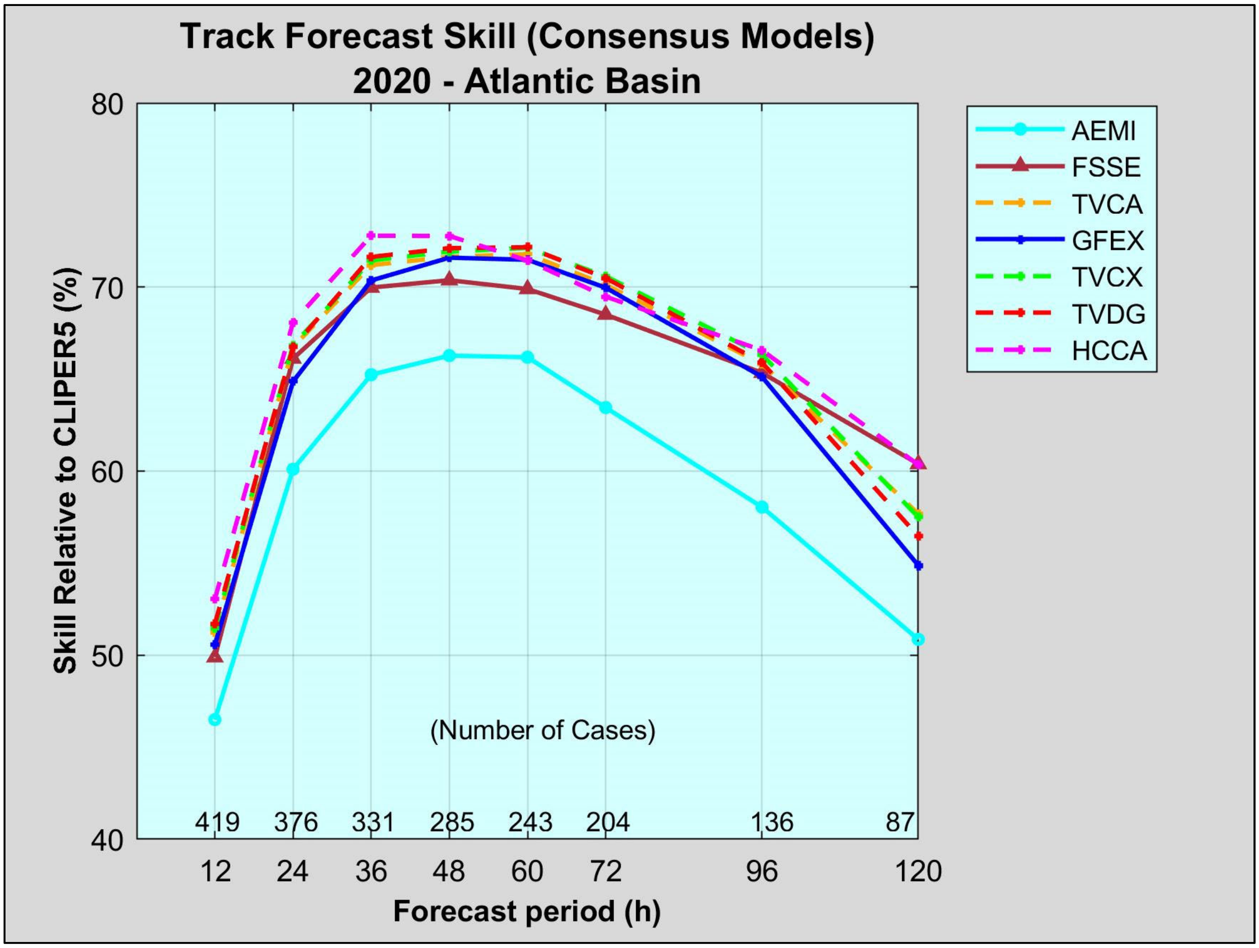


Figure 7. Homogenous comparison of OFCL, GFSI, EMXI, EGRI model track biases (n mi) at verifying 120-h forecasts for the Atlantic basin during the 2018-20 period. The red 'X' depicts the mean bias for each model.



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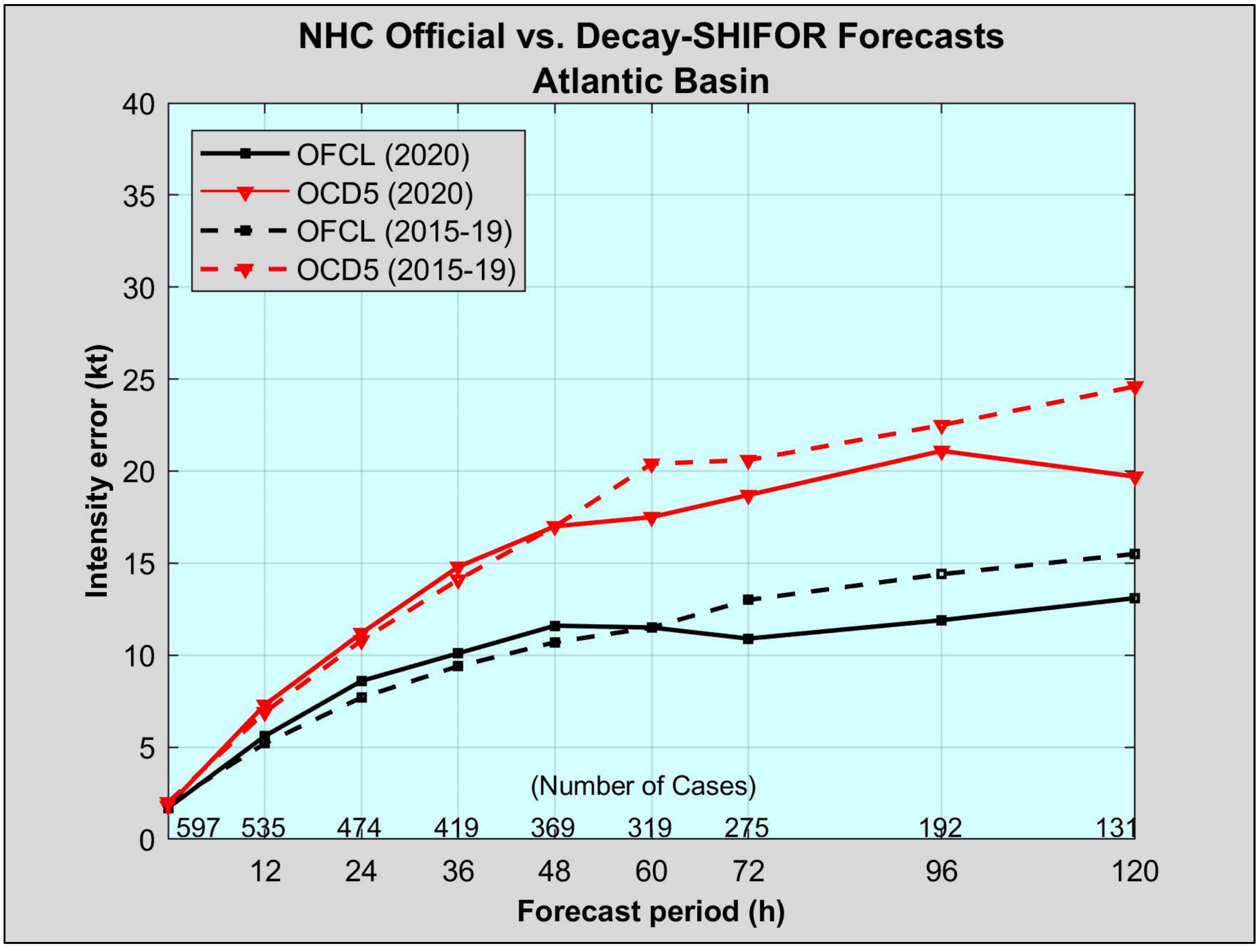

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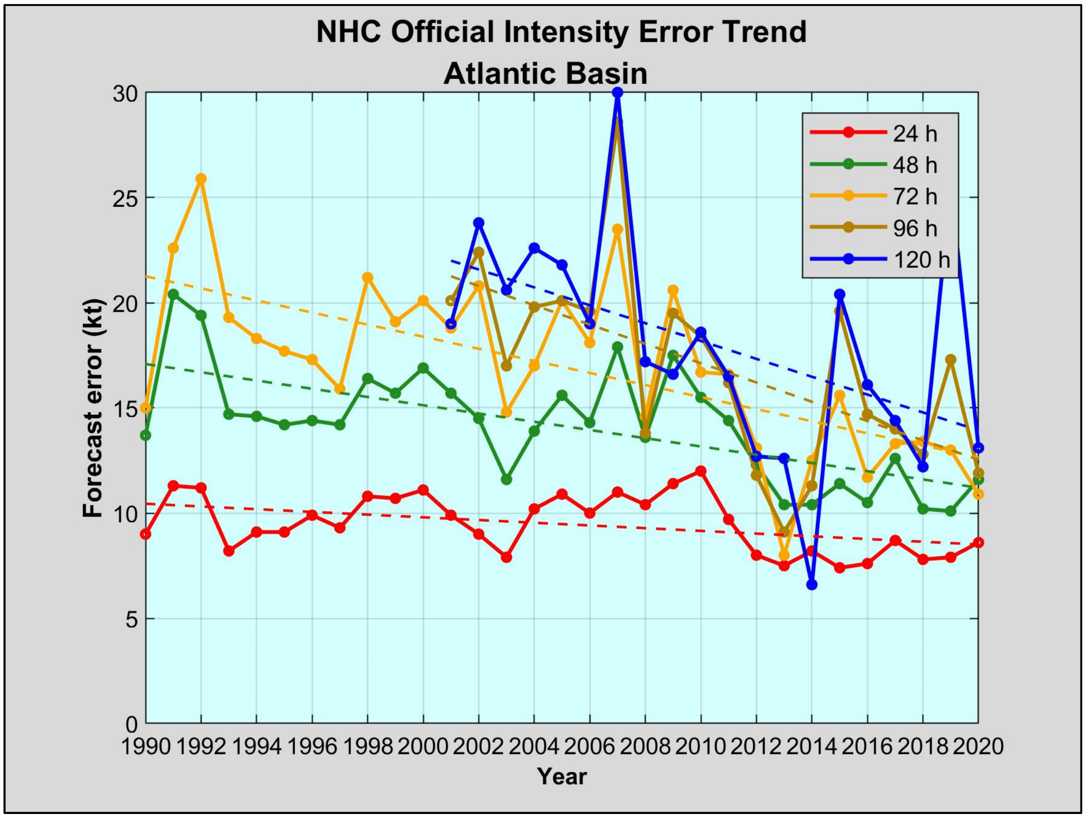

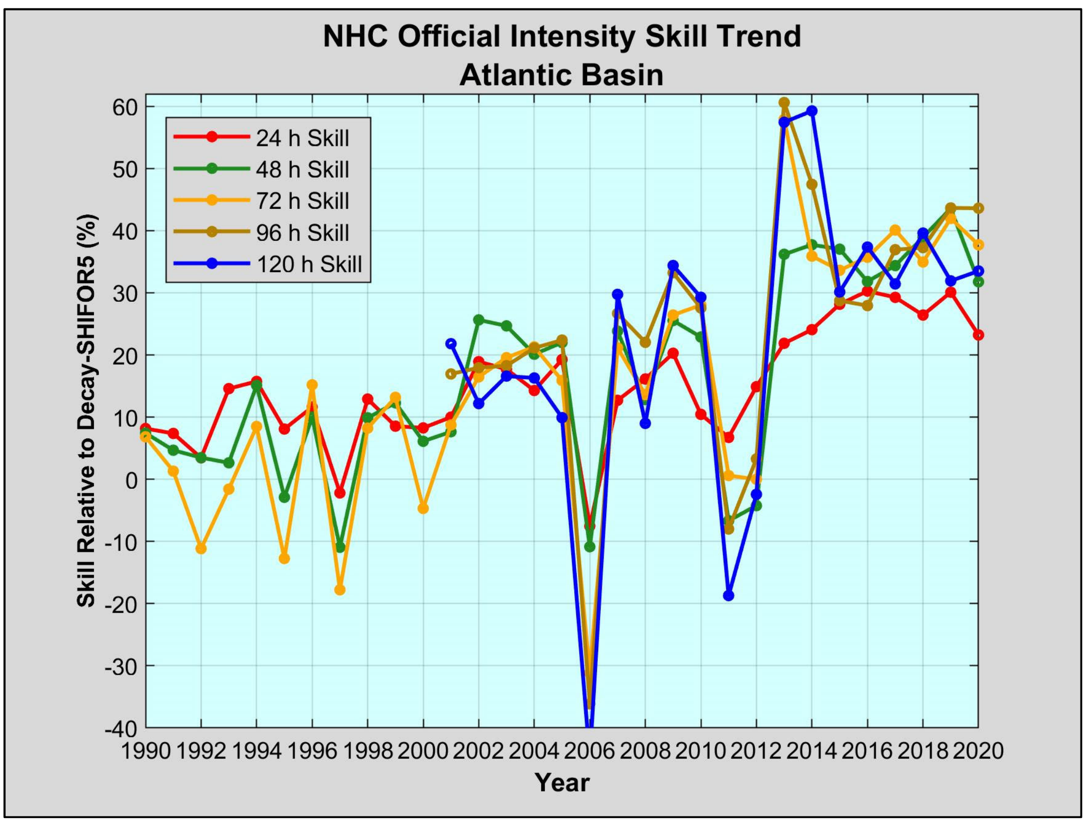

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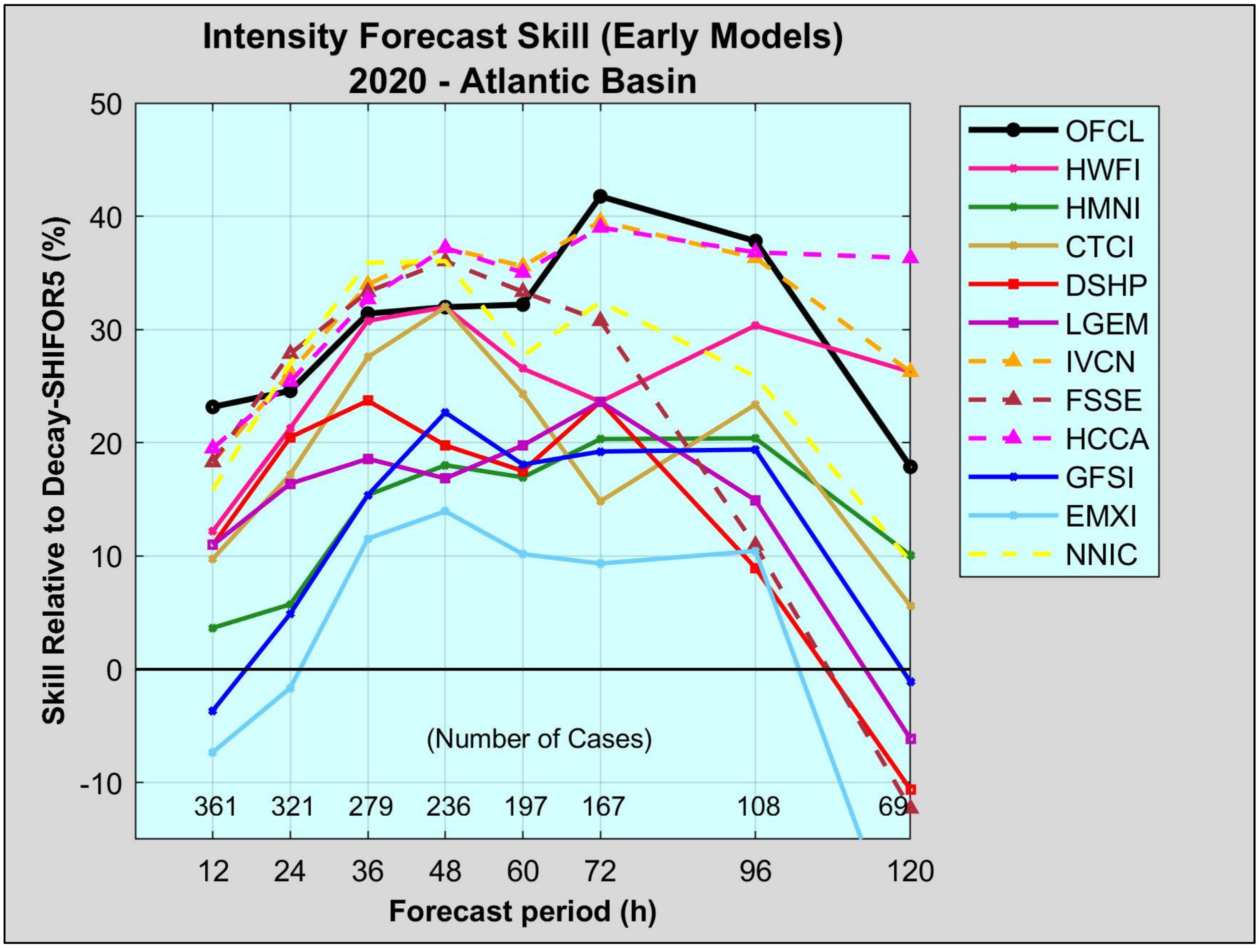

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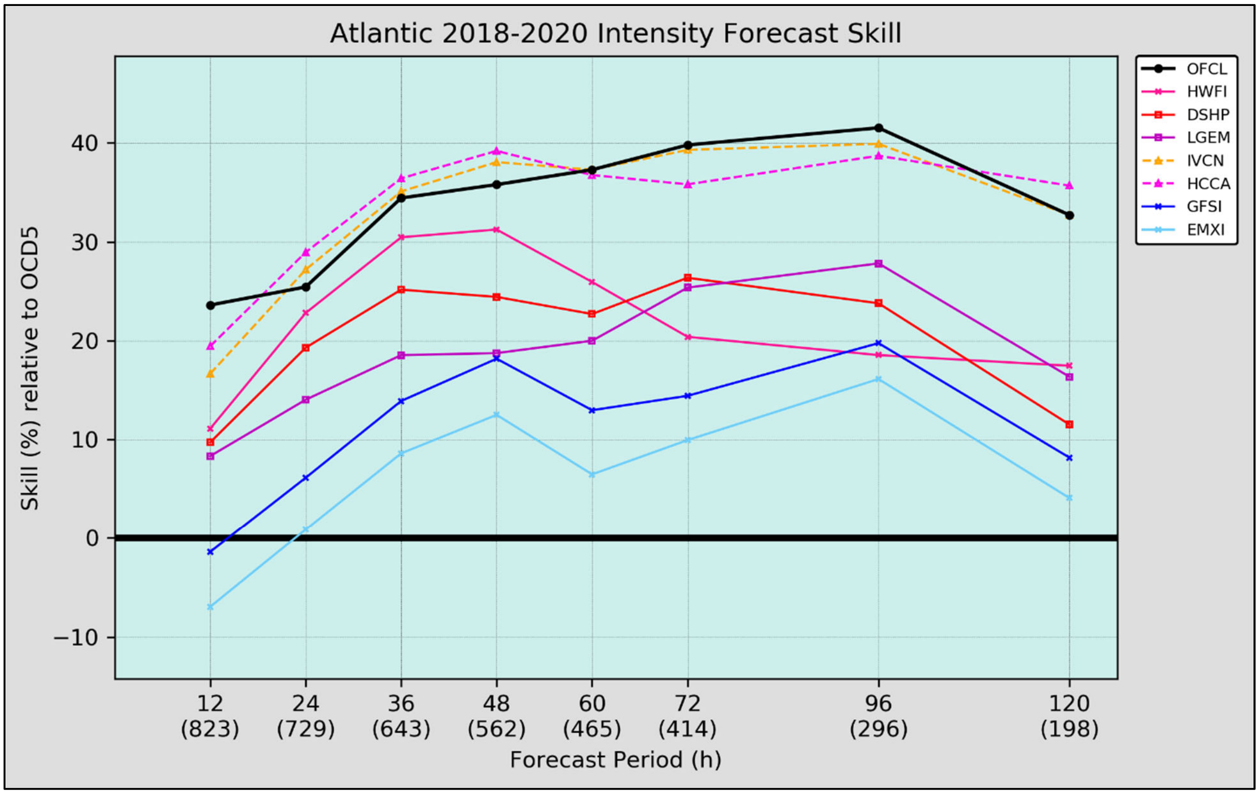

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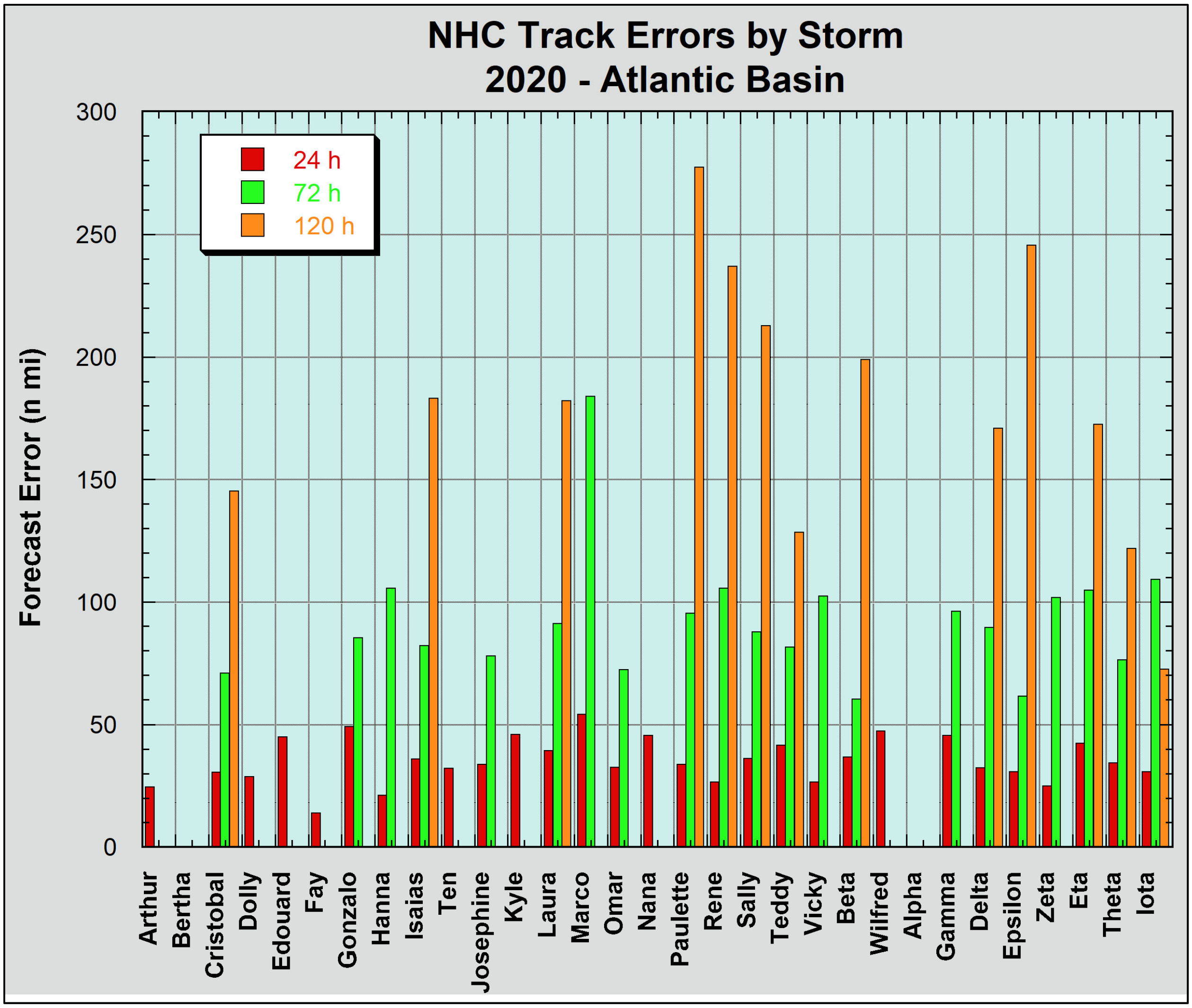

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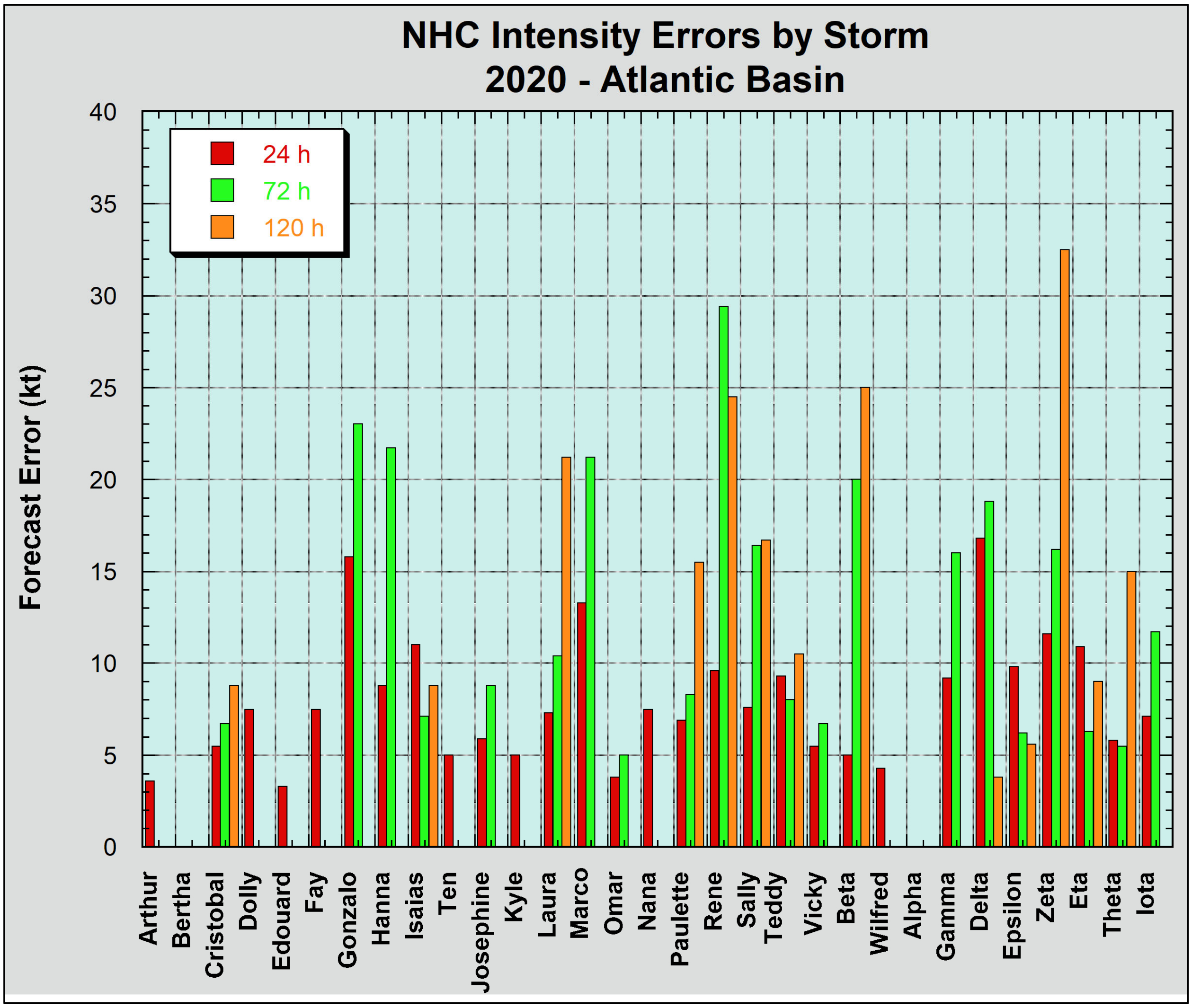


Figure 14. 2020 NHC official intensity errors by tropical cyclone at 24, 72, and 120 h.

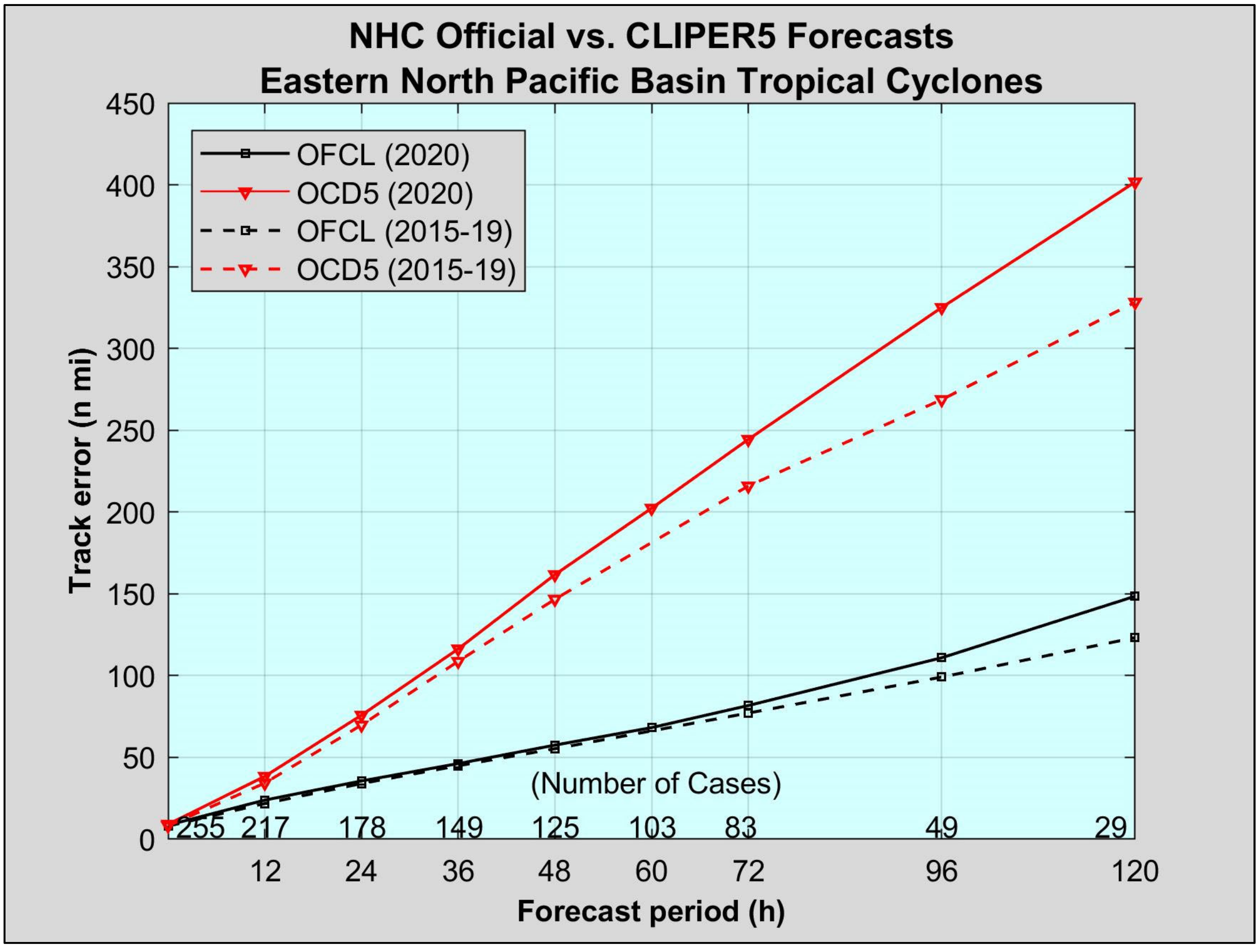


Figure 15. NHC official and CLIPER5 (OCD5) eastern North Pacific basin average track errors for 2020 (solid lines) and 2015-2019 (dashed lines).

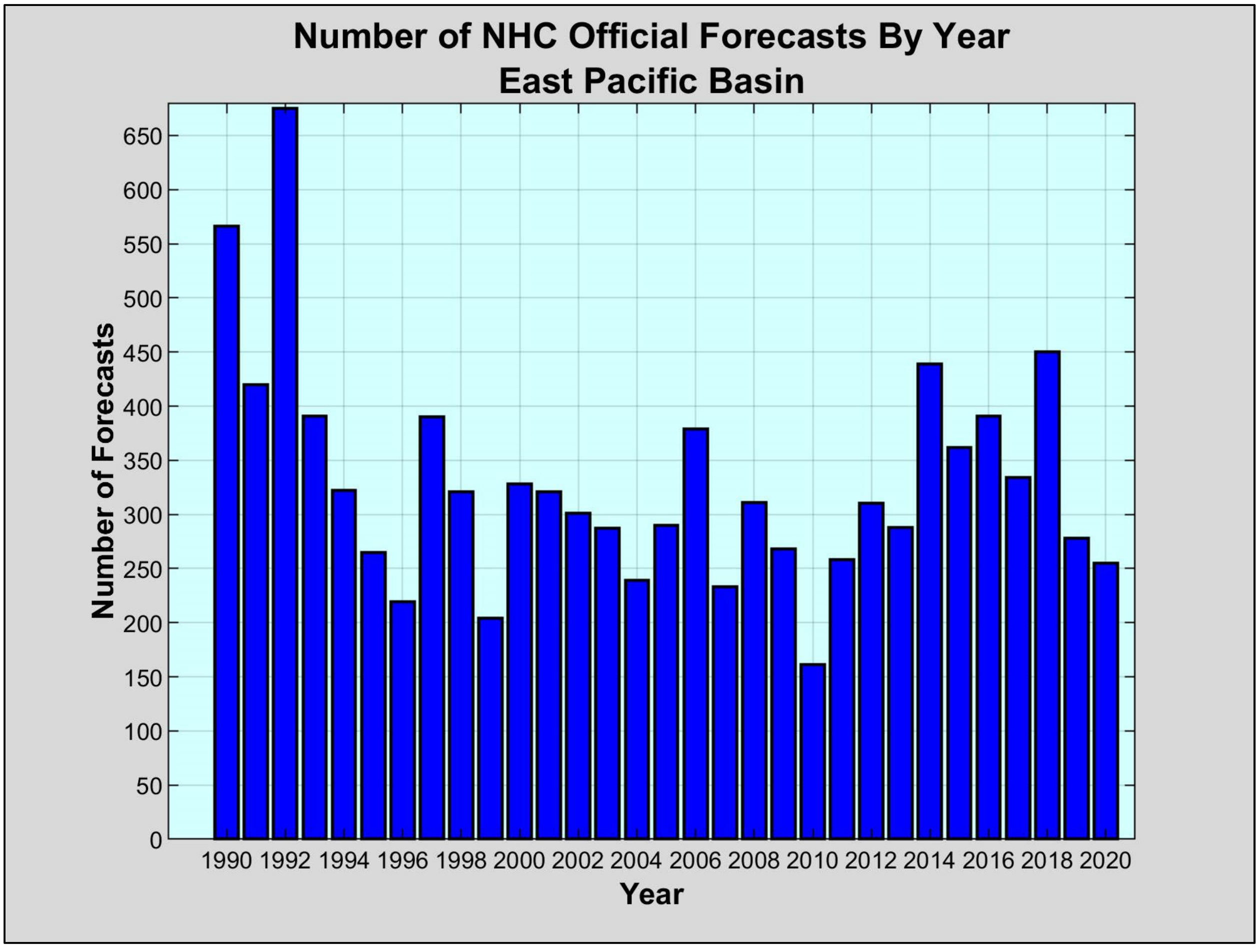
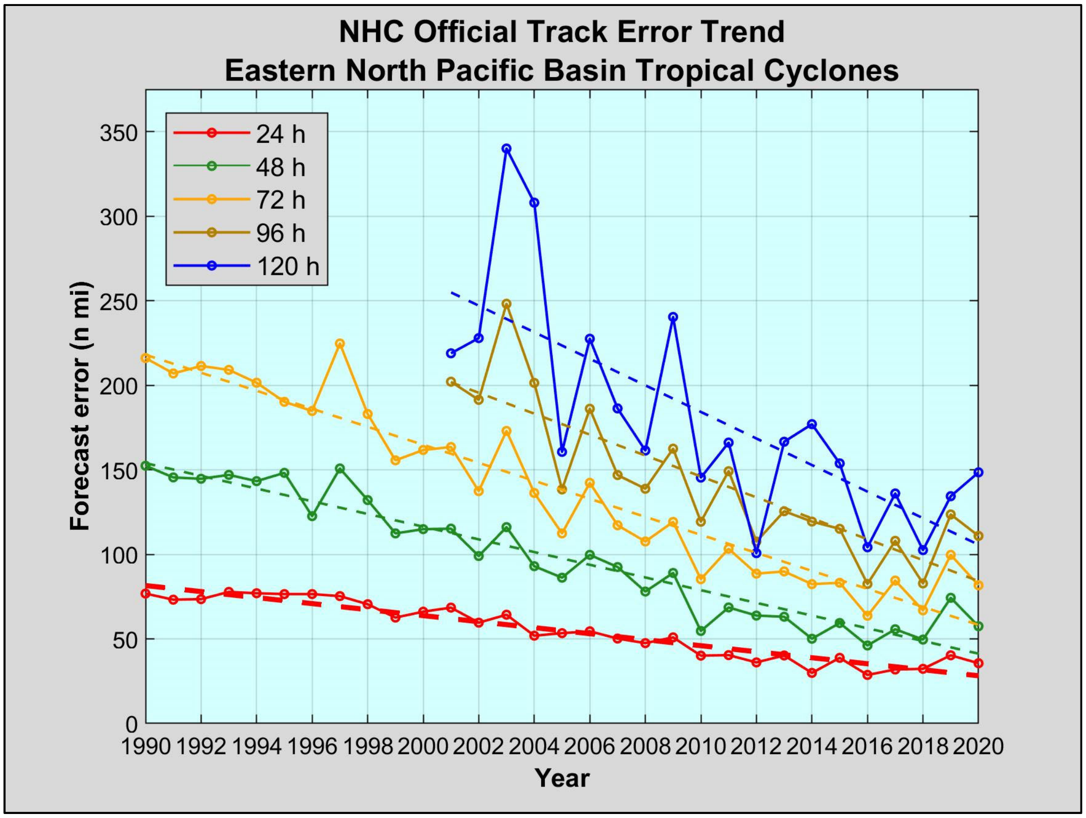


Figure 16. Number of NHC official forecasts for the eastern North Pacific basin stratified by year.



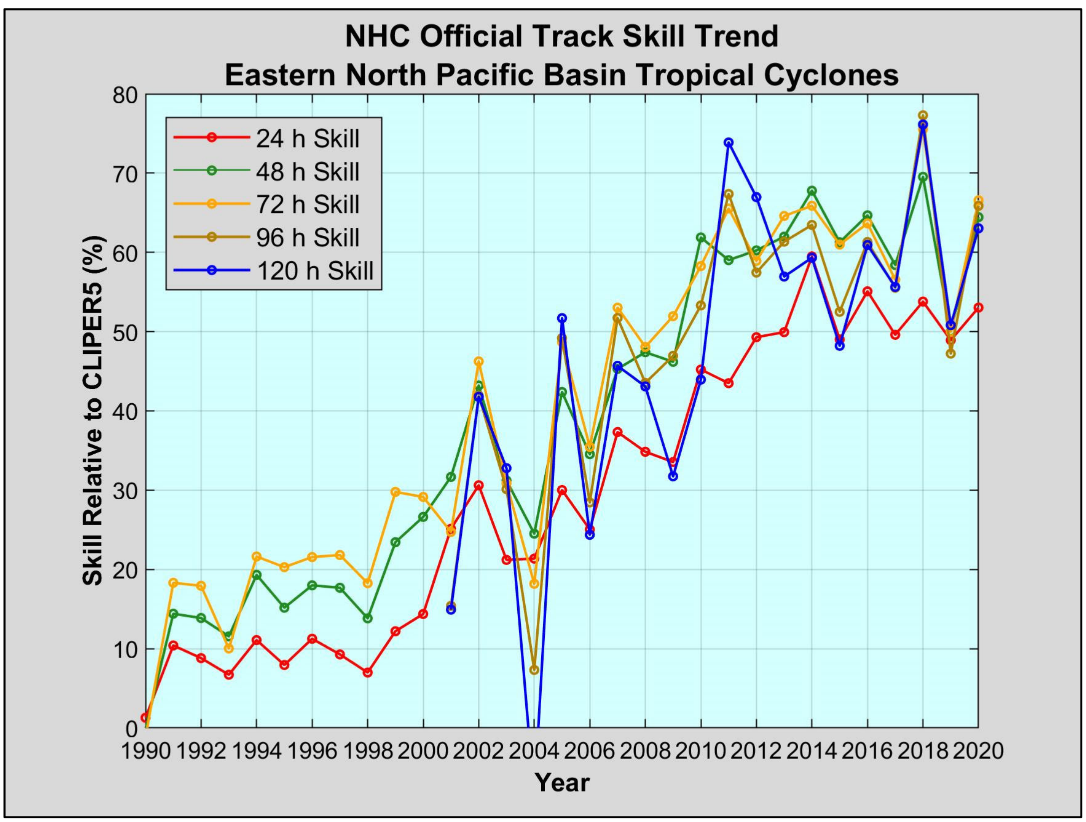
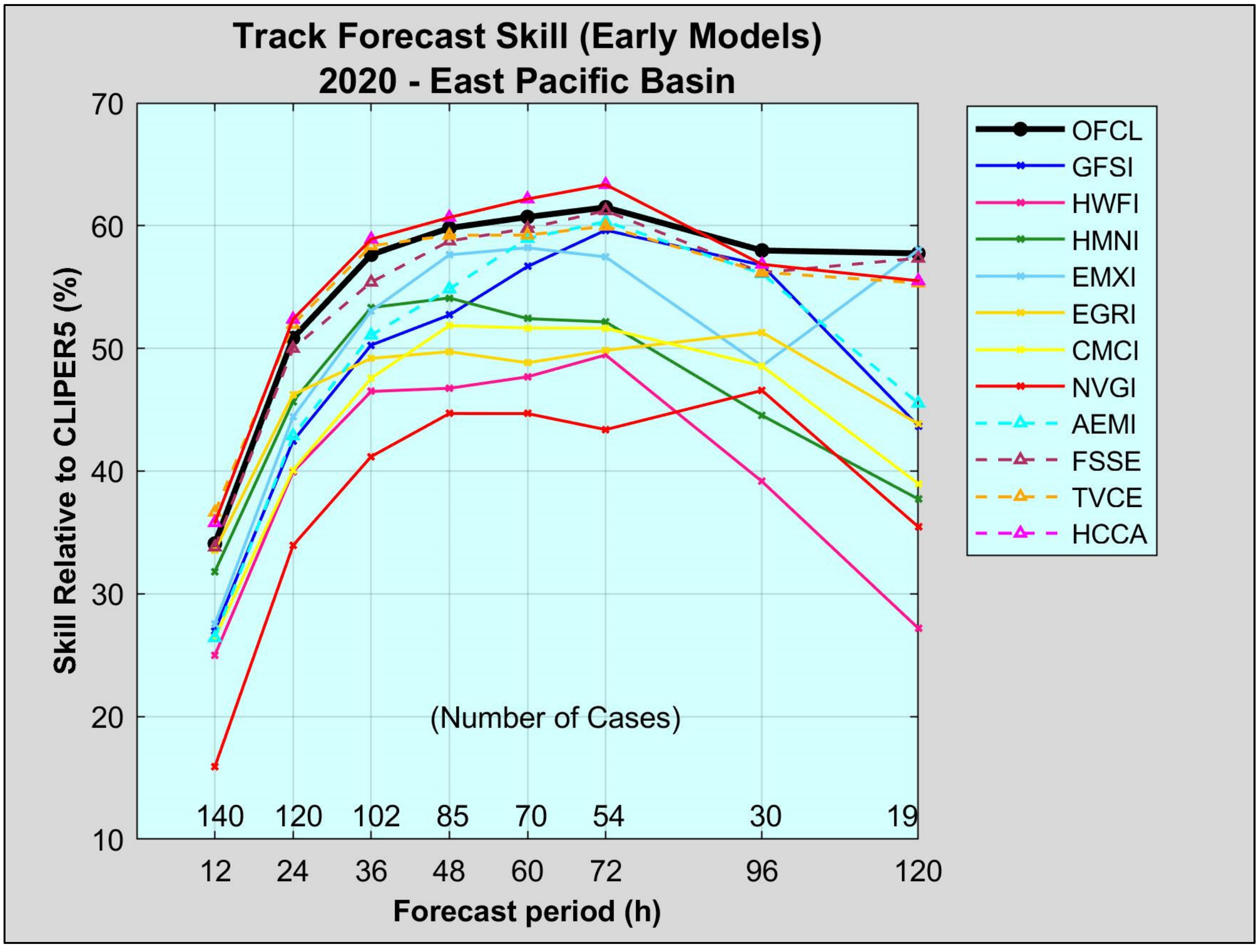


Figure 17. Recent trends in NHC official track forecast error (top) and skill (bottom) for the eastern North Pacific basin.



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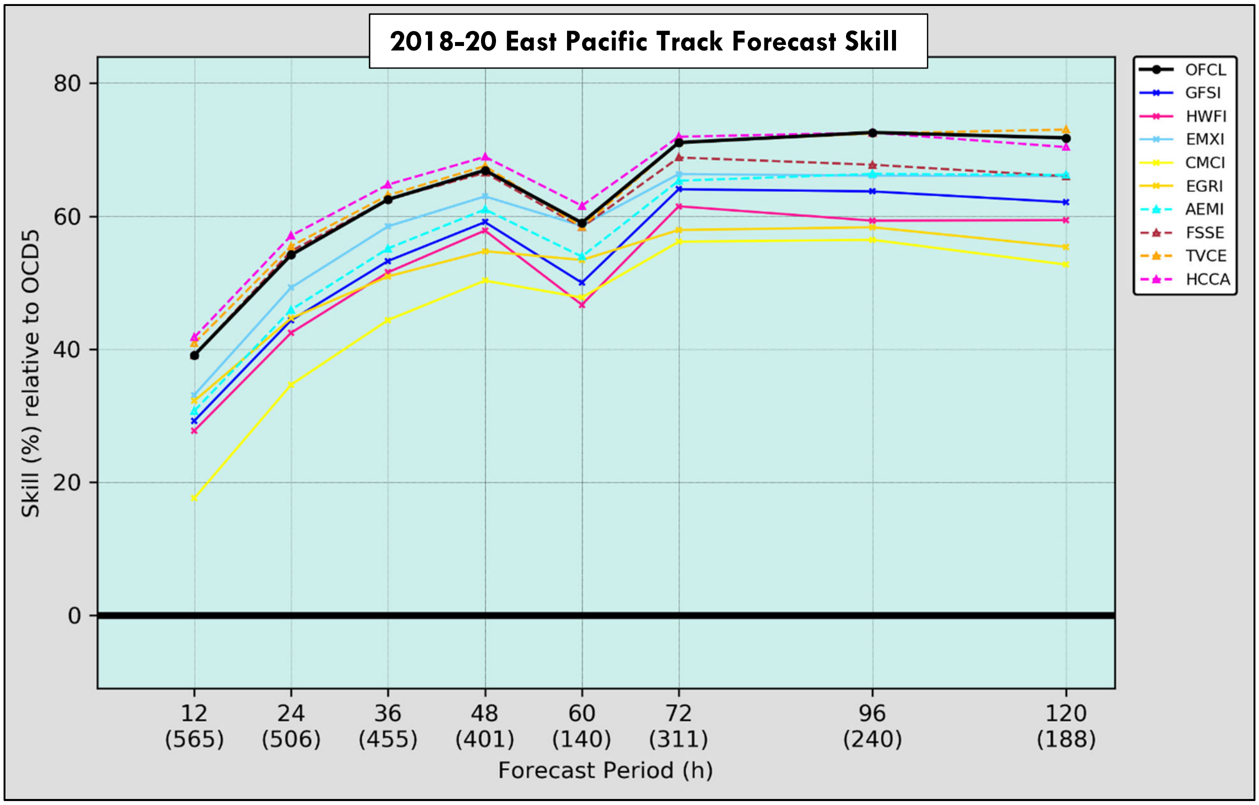

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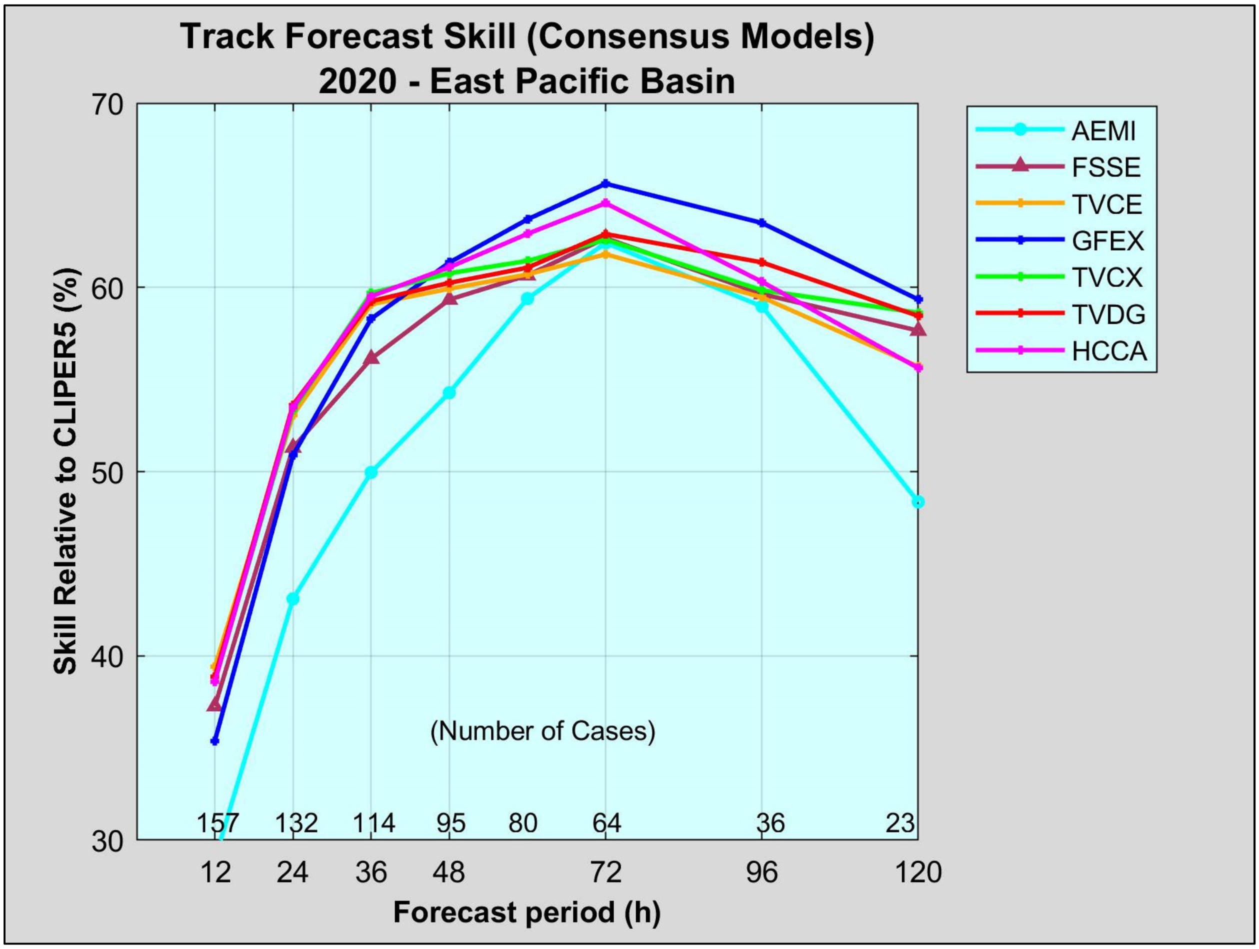
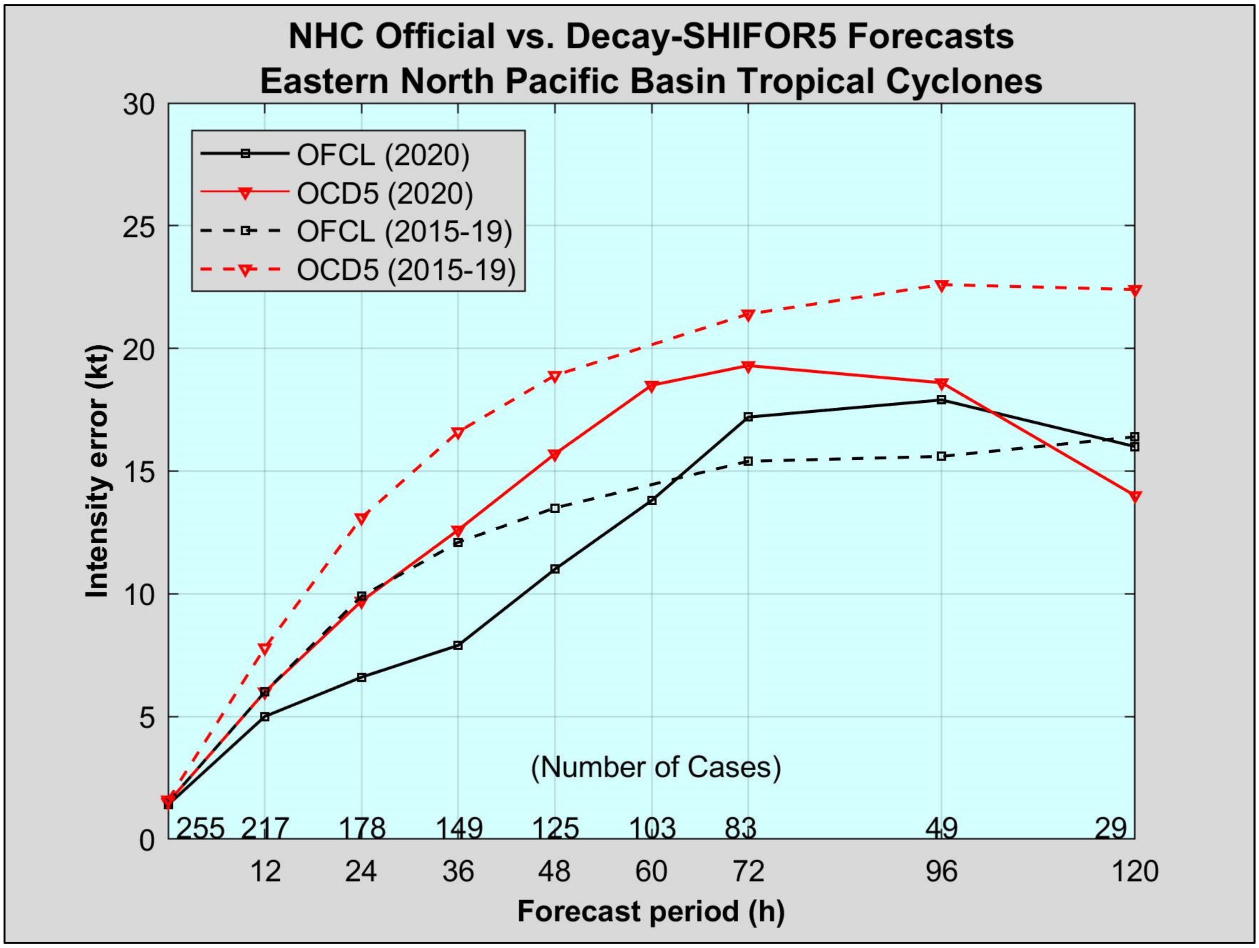


Figure 20. Homogenous comparison of the primary eastern North Pacific basin track consensus models for 2020.



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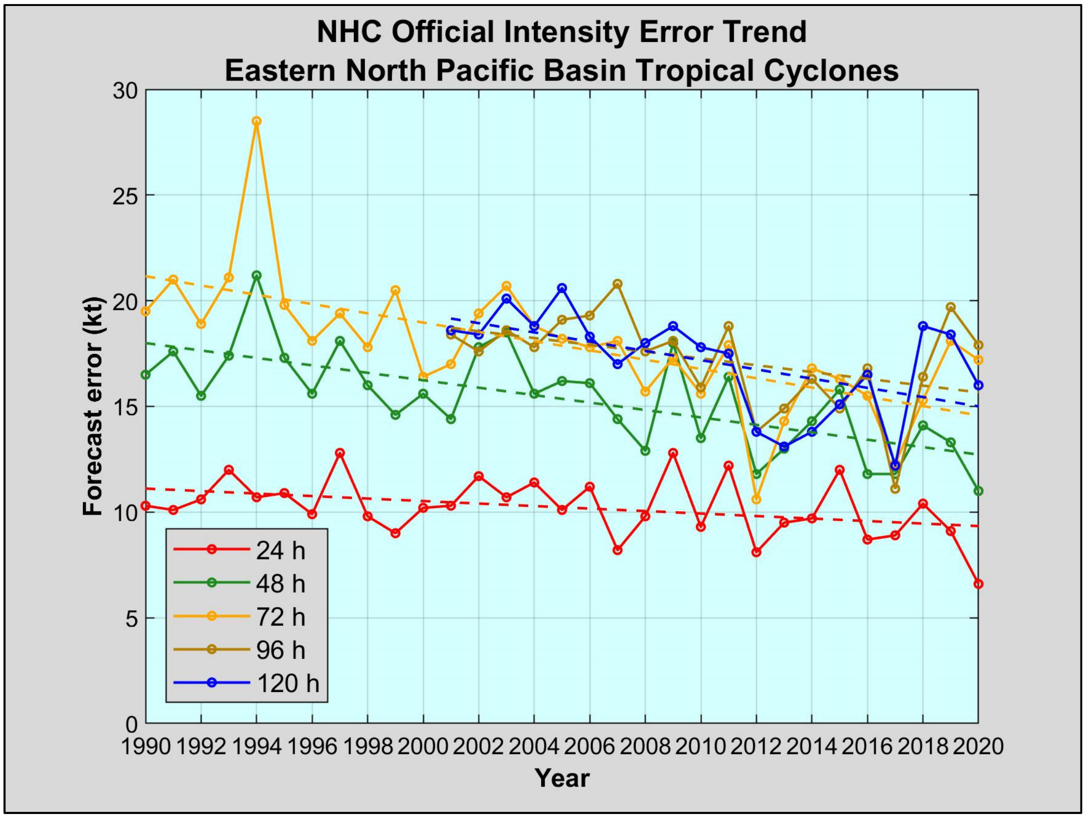

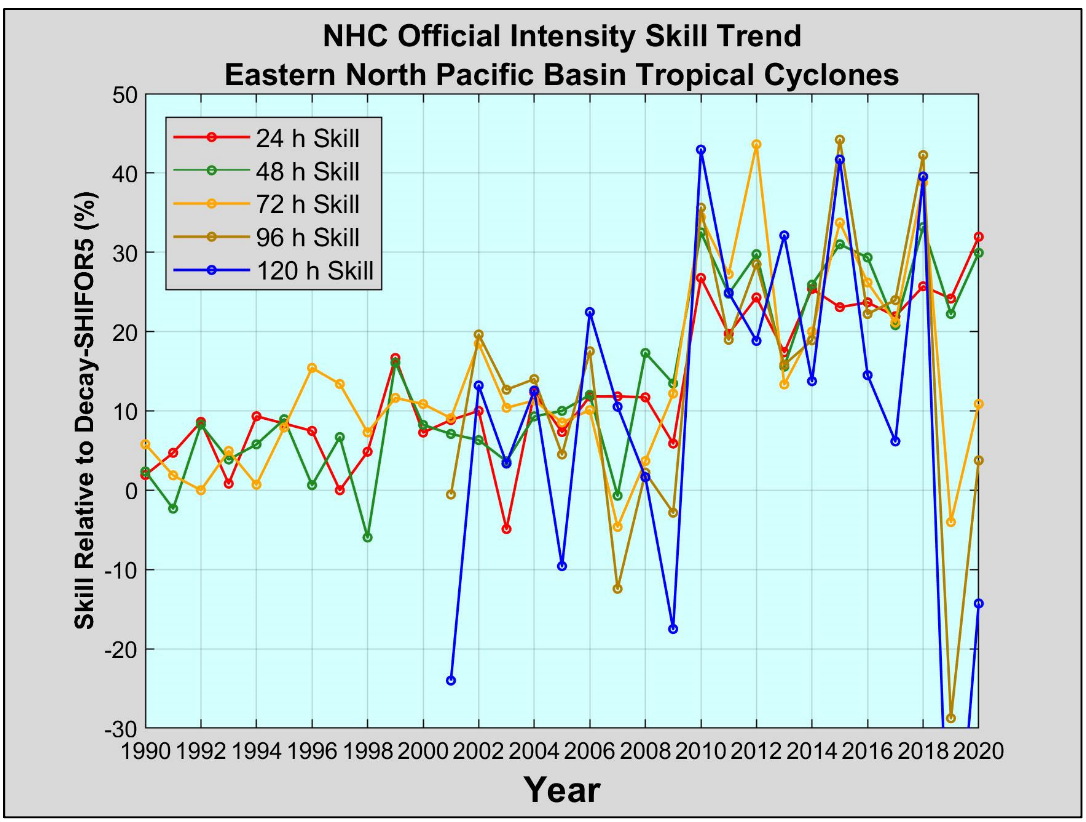

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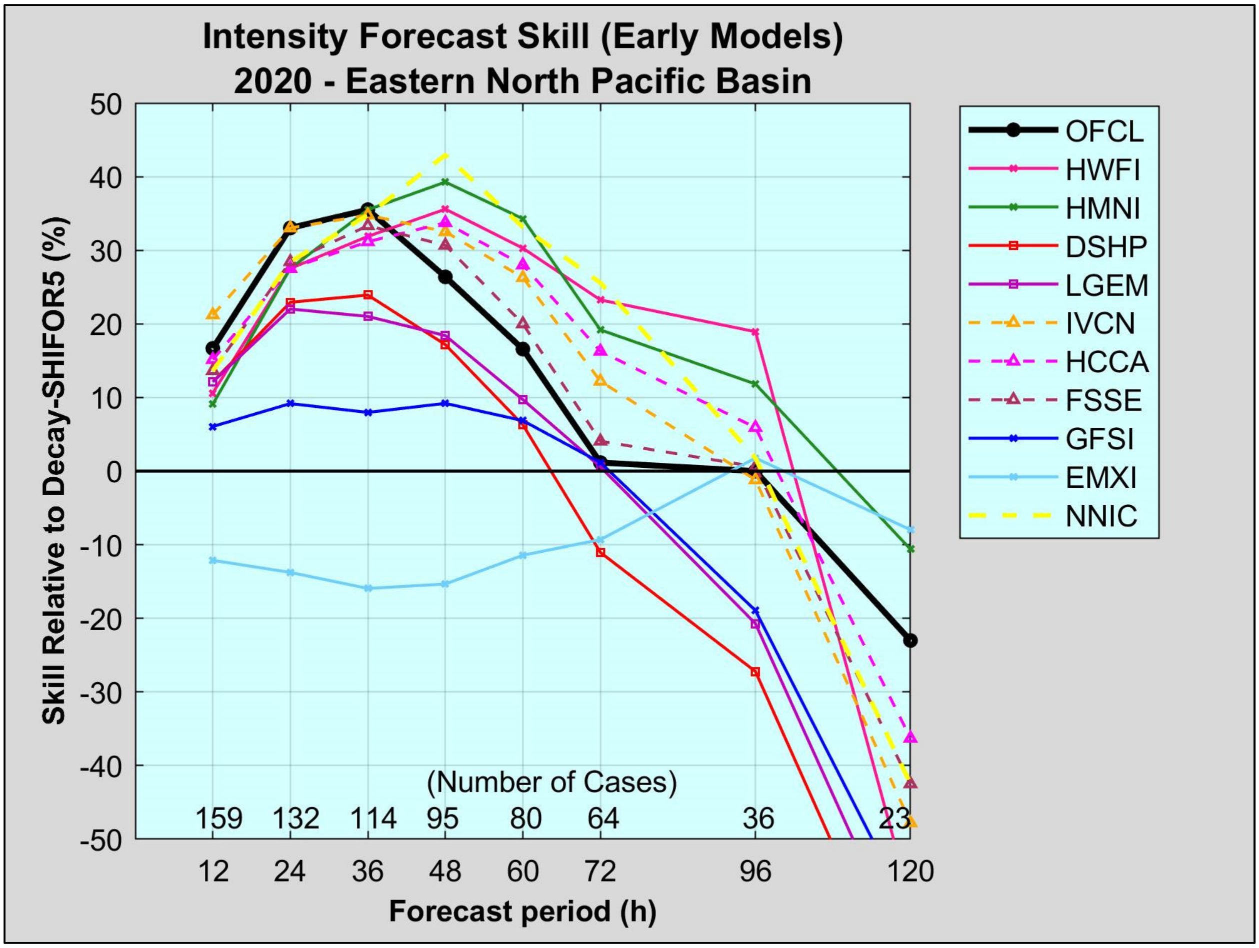


Figure 23. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2020.

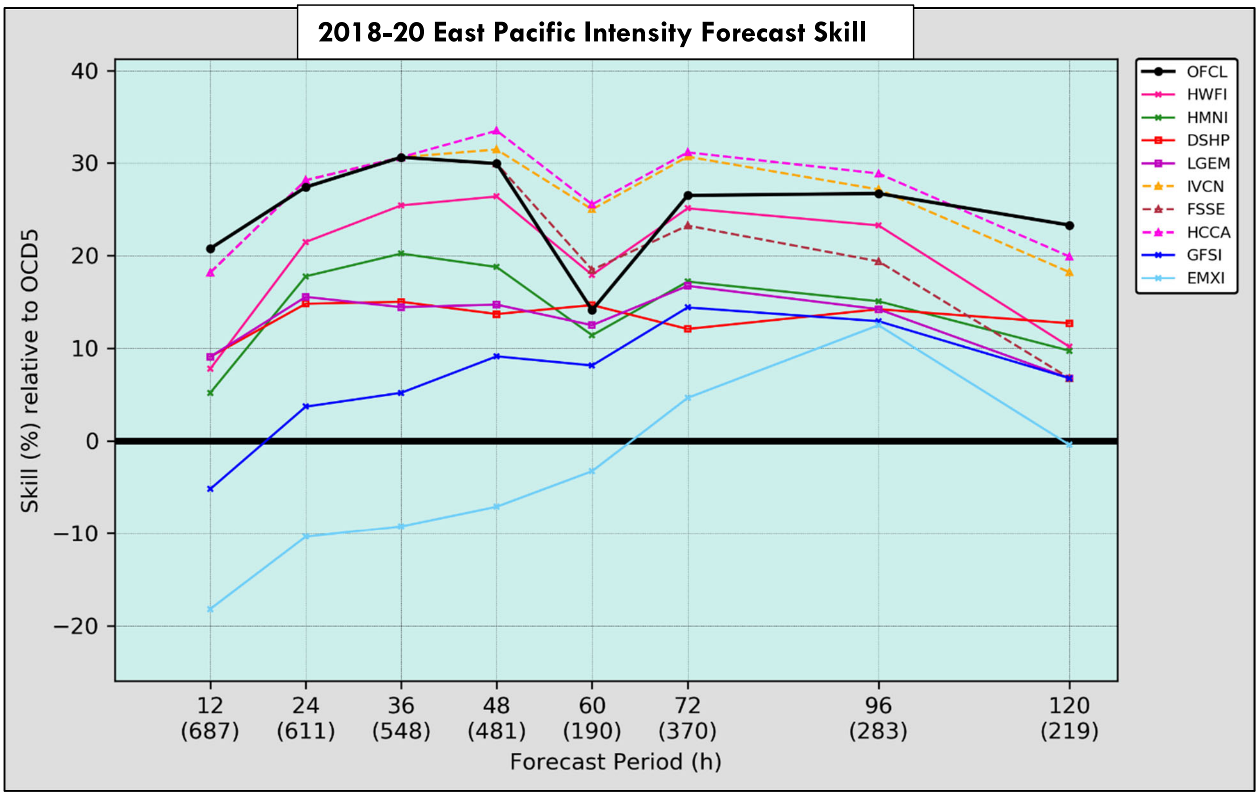
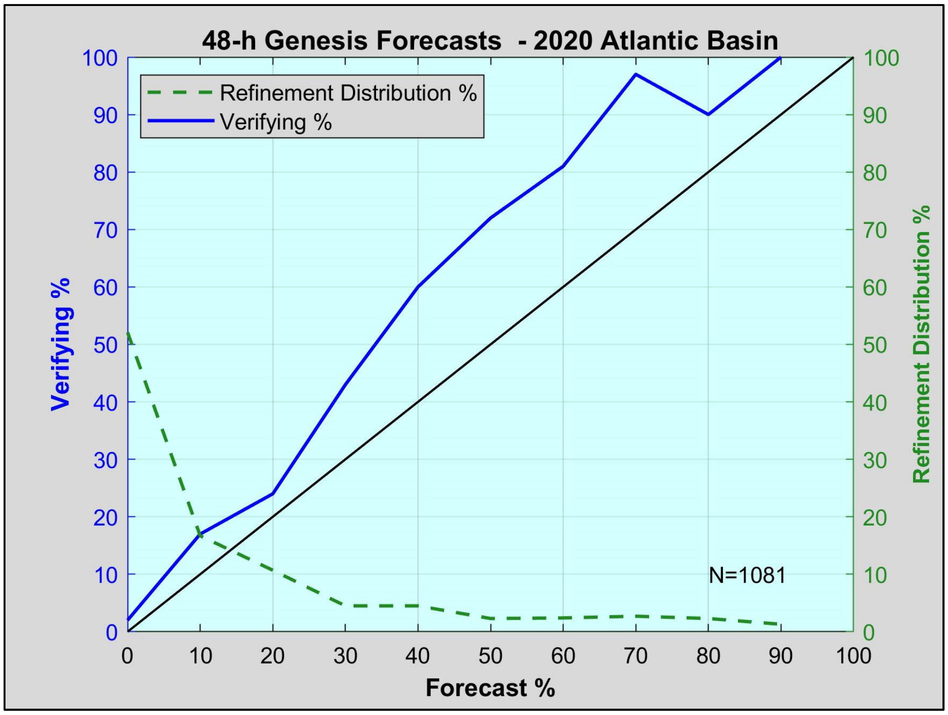
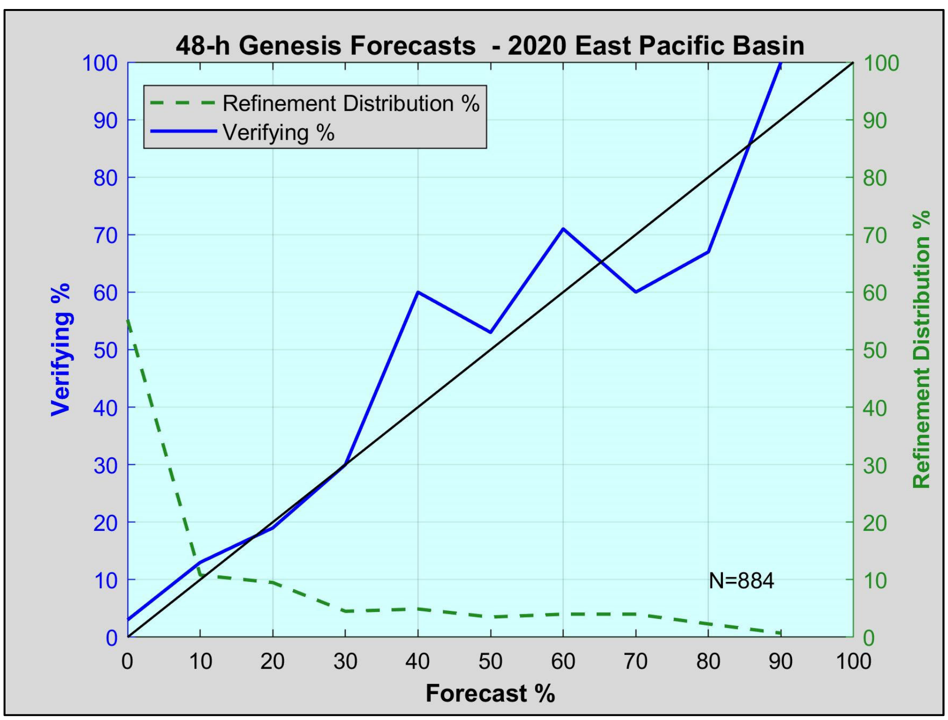


Figure 24. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2018-2020.





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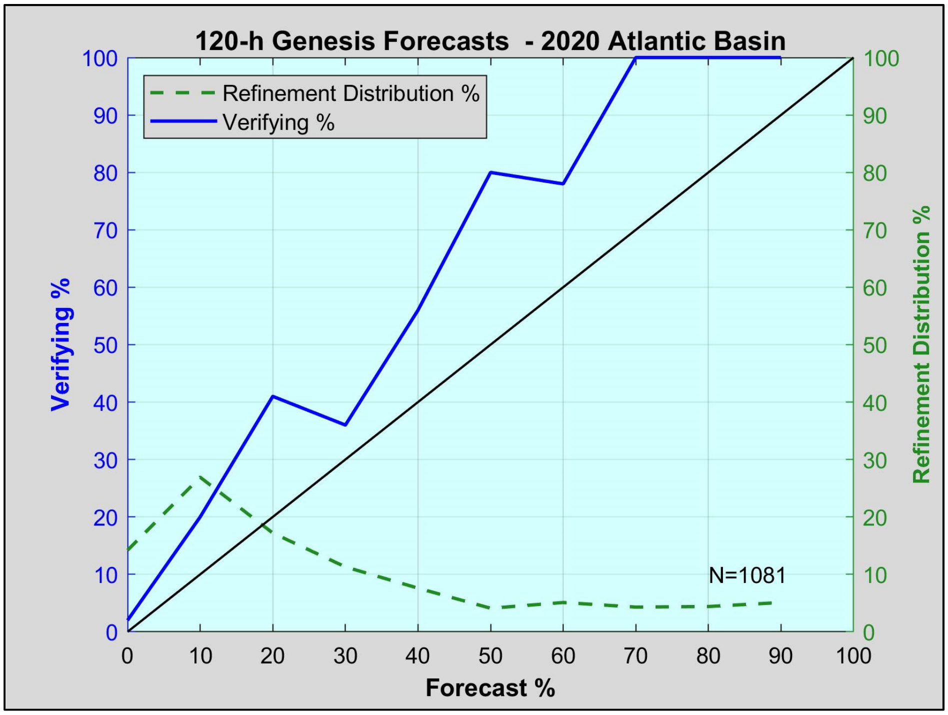

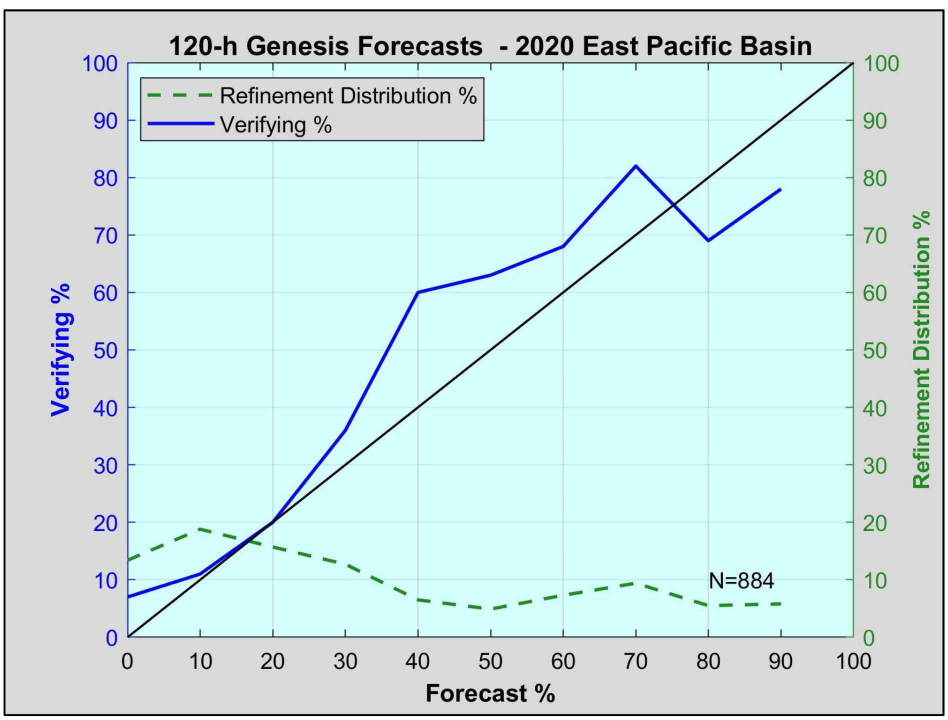

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